Application of Fractional Frequency Reuse Technique for Cancellation of Interference in Heterogeneous Cellular Network

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF

Master of Technology

in

ELECTRONIC SYSTEMS AND COMMUNICATION

by

CHIRANJIBI SAMAL

**Department of Electrical Engineering
National Institute of Technology, Rourkela
2014**

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CERTIFICATE

This is to certify that the thesis entitled, "**APPLICATIONS OF FRACTIONAL FREQUENCY REUSE TECHNIQUE FOR CANCELLATION OF INTERFERENCE IN HETEROGENEOUS CELLULAR NETWORK"** submitted by **Mr**. **CHIRANJIBI SAMAL** in partial fulfillment of the requirements for the award of Master of Technology Degree in **Electrical Engineering** with specialization in **"ELECTRONIC SYSTEMS AND COMMUNICATION"** at National Institute of Technology, Rourkela (Deemed University) is carried out by him under my supervision and guidance.

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Declaration

I certify that

i.   The work carried out in this thesis is original and has been done by myself under the guidance of my supervisor

ii.   For writing the thesis, I followed the guidelines provided by the institute.

iii. Whenever I used content in this thesis from another source, I have given due credit to them by citing them in the text of the thesis and giving their details in the references

iv.   The work has not been submitted to any other Institute for any degree.

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ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

3GPP   3rd Generation Partnership Project

LTE   Long Term Evolution

FFR   Fractional Frequency Reuse

FUEs   femtocells users

ITU   International Telecommunication Union

1G   First Generation

2G   Second Generation

3G   Third Generations

4G   Fourth Generations

FBSs   Femtocell Base Stations

UMTS   Universal Mobile Telecommunications System

E-UTRAN   Evolved UMTS Terrestrial Radio Access Networks

QoS   Quality of Service

SCs   Sub-Carriers

UE   User Equipment

F-BS   Femtocell Base Station

F-UE   Femtocell User Equipment

F-ALOHA   Frequency ALOHA

DFP   Dynamic Frequency Planning

LIP   Least Interference Power

CCI   Co channel Interference

IP   Internet Protocol

ADSL   Asymmetric Digital Subscriber Line

LTE-A	LTE Advanced
HetNets	Heterogeneous network
HeNB	Home Evolved NodeB
eNodeB	Evolved NodeB
ICIC	Intercell Interference Coordination
WiMAX	Worldwide Interoperability for Microwave Access
MNO	Mobile Network Operators
GPS	Global Positioning System
MUE	Macro User Equipment
HUE	Home User Equipment
NLM	Network Listen Mode
REM	Radio Environment Measurement
RIP	Received Interference Power
NLM	Network Listen Mode
FFR	Fractional Frequency Reuse
SFR	Soft Frequency Reuse
SINR	Signal to the Interference and Noise Ratio
CDF	Cumulative Distribution Function

ABSTRACT

The continuously growing number of mobile devices in terms of hardware and applications augments the necessity for higher data rates and a larger capacity in wireless communication networks. The Long Term Evolution (LTE) standard was designed to provide these mobile users with a better throughput, coverage and a lower latency.

This thesis studies a specific area in Heterogeneous Networks; the subject of femtocells. The aim of femtocells is to provide better indoor coverage so as to allow users to benefit from higher data rates while reducing the load on the macro cell. Femtocells were proposed for Long Term Evolution (LTE) for indoor coverage. It is achieved using access points by home users. However, co-channel interference is a serious issue with femtocells that may dramatically reduce the performance of femto and macrocells. The system capacity and throughput decreases. As femtocells use the same spectrum as the macrocells, and the femtocells are deployed without proper planning, interference from femtocells to macrocells becomes a major issue.

In this thesis, the interference from femtocells to macrocells is studied and a solution for the mitigation of this kind of interference is suggested using FFR mechanism. In our proposed scheme for interference avoidance, femtocells use those frequency sub bands which are currently not being used within the macrocell, the process of assigning the frequency bands is based on FFR. The simulation results suggest that the suggested technique enhances total/edge throughputs, and optimizes the SINR and CDF of femtocells users (FUEs) and reduces the outage probability of the network.

Chapter 1

INTRODUCTION

1. INTRODUCTION

1.1 OVERVIEW

Cellular phones play a dominant part in modern day life. Nowadays it's very uncommon to see a person without access to a mobile phone. Latest facts from ITU [9] reveal that by the end of 2013 there are 6.8 billion mobile phone users and by 2014 this will exceed the world population. Since the introduction of smart phones in early 2000s the numbers of online users have grown rapidly and with that the data rates in cellular networks have increased to greater proportions. What these trends indicate is whilst network penetration is spreading to every part of the earth, mobile phone and internet is becoming more and more affordable to the commoner. With these technological advancements arises the need to increase network capacity and speed. As the number of subscriber's increases and data rate demand rises, traditional macrocells find it difficult to make demands meet especially in densely populated places.

The cellular market has always been a demanding, ever evolving market. Since the introduction of mobile phones in the early 1990s, digital mobile phones have grown to reach around 5 billion subscriptions worldwide, around 76% of the world population [1]. In parallel, the Internet has been also growing, to reach 1.6 billion users worldwide, nearly 25% of the world population [2]. Blogs, social networks, video streaming and video gaming are continuously pushing the Internet traffic to its limits.

The current cellular systems have started evolving since the 1980s. The introduction of First Generation (1G) mobile networks aimed at providing voice only services. It was based solely on analog technologies. The 1G system has been replaced soon by

Second Generation (2G) digital mobile systems. The introduction of Third Generation (3G) mobile services [3] has merged both the digital mobile technology and the Internet technology. This merging boosted markets, promoting the fact that consumers are getting too attached to their mobile phones and increasing their hours of stay online. This also expanded the market for new bandwidth demanding applications that encourage more mobile usage.

The current specifications of Fourth Generation (4G) wireless cellular standards promise hundreds of Mbit/s that should reach up to 1Gbit/s for low mobility communications. With the ever increasing number of mobile users in the same territory, these rates might be difficult to achieve without optimized signaling, modulation, coding and interference resistance mechanisms. Nowadays, an emerging trend has been put into action to virtually extend the territory covered by a certain provider, which is: layering cellular networks, resulting in the formation of small cells within larger cells, as in Figure 1.1.

Since shrinking the cell size is the simplest and most effective way of increasing wireless throughput [7, 8], hence, was the introduction of indoor base stations forming picocells and recently femtocells [10]. The introduction of these small coverage networks requires also optimized operational mechanisms in order to co-exist with larger macrocell networks. Typically, femtocells form a coverage area that layers the macrocell coverage area. The two layers share the physical space, and form smaller cells that provide indoor coverage within the vicinity of larger cells, as shown in Figure 1.1. Femtocells are expected to have a very strong penetration rate at homes, offices and malls. End users will install their Femtocell Base Stations (FBSs) on their own.
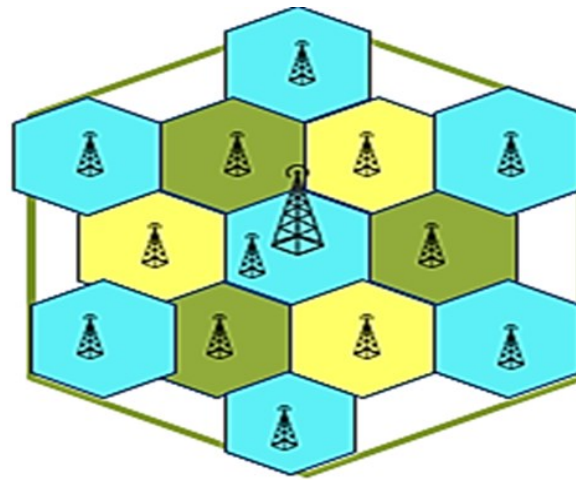
Macro base Stations

Femto Stations
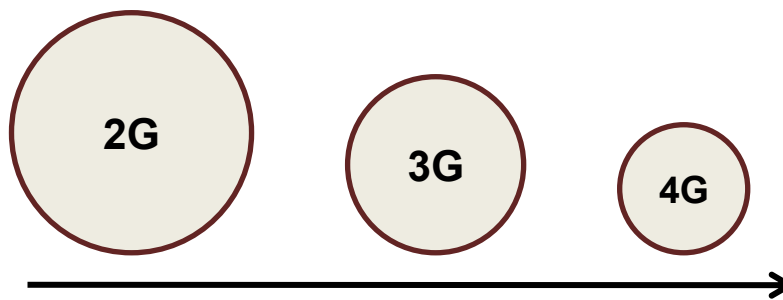
As throughput demand and usage increases, cell size decreases

Figure 1.1 Structure of Femtocell

FBSs installation will be done in a convenient plug and play manner, and hence, non-coordinated ad-hoc deployment is inevitable. Such deployment is more likely to introduce interference [11], which will adversely affect the capacity of the radio system in addition to the quality of the individual communication links.

In 2008 the Long Term Evolution (LTE) was introduced to cater these needs and with that the femtocell concept was introduced. As a result of this, in a cellular networks mixture of macro and other smaller cells, such as pico and femto cells, are expected to coexist in the future. These new cells provide the network the capability

to provide satisfactory services to places having high load, especially in densely populated areas and also to the cell edges where signal strength from macrocells can be low. But there are some adverse effects that can arise because of this coexistence. As an example, interference among different cells can occur, especially among femtocells and macrocells because femtocells use the same spectrum used by macrocells and cell planning is also not performed like in picocells. This is also called inter cell interference. The main reason for the unplanned deployment of femtocells is that they are installed by home users, not the network operator.

1.2 MOTIVATION

LTE is developed by the 3rd generation Partnership Project (3GPP) in order to make sure the effectiveness of its standards in the long term. Recently it is also known as 4th generation technology. LTE is the evolution of 3rd generation mobile technology, also called as Universal Mobile Telecommunications System (UMTS). The main challenges for LTE is to come up with new radio access technology so that high data rates, low latency can be offered. LTE is also known as E-UTRAN (Evolved UMTS Terrestrial Radio Access Networks).

For indoor coverage enlargement the LTE has grown a femtocell. Femtocells have been attracting much attention recently for indoor coverage. The femto cell accompanies differing advantages to both consumers and operators, such as improved system capacity, increased indoor coverage, made smaller capital, operation expense and Quality of Service (QoS). The femtocell could be a drawing attention solution due to becoming larger data services and indoor phone calls but not enough macrocell coverage.

Nevertheless, interference difficulty between the macrocell and the femtocell should be resolved .It can be noticed that some operators did not even grow positively in terms of voice revenue and that data revenue growth was more dominant.

1.3 LITERATURE SURVEY

In [12] Jeffrey G. et al. Presents an overview of femtocells, describes their important visible features, and predicts preliminary growth in coming years, including reduction in the size of the cell and the importance of femtocell in the future.

In [13] Chandrasekhar.et al.it gives the idea about the mechanics and profession fight for femtocells and explains the state of the art on each front. It also explains the technical dispute problems for femtocell and gives initial knowledge for reducing it.

Vishnupriya.P. et al. [14]. In this paper, it shows the techniques how to mitigate interference mitigation in macrocell and femtocell and it suggests how to increase the total network accomplishment using frequency reuse techniques. The throughput can be enhanced by considering inner cell radius and the frequency distribution to the macrocell together for the division of cells in the entire coverage zone..

Bouras et al. In paper [15], a frequency reuse preference from among choices, techniques is suggested; desire to decrease cross-tier CCI among femtocells and macrocells. Every macrocell is detached into outer and inner scope and the frequency is divided into FFR 1 and FFR 3 respectively.

Avani Dalal.et al. In [16] self-configuration fractional frequency reuse scheme, subset of sub-carriers (SCs) are allocated to the cell edge of femtocells and all SCs are utilized at the cell center. According to this scheme the F-BS gets the periodic report about the user equipment (UE) from F-UE. If interference level is bigger than the threshold value, then FFR is performed on the neighboring F-BS by selecting a

distinct set of SCs for cell edge and also reduces the cell-center radius till the user lies at the cell-edge.

Bharucha.et al. This approach [17] manipulates the cell ID of the home evolved nodeBs (HeNBs) and also reduces the interference caused from common reference symbol, physical downlink control channel etc to trapped macro UE. This method is compliant in case of closed access femto-cells and signaling is not required. Thus, by transmitting data to femto UEs from HeNB the performance of trapped macro UEs is improved.

Zahir et al. In this paper [18] give a rundown important idea of femtocells and the bigger question come up against a situation in the bigger scale arrangement. The important question of interference management is talking over within the specific aspect with its classes in femtocells and the answers suggested to control interference has been given a rundown. It also gives the idea about the present femtocell uniformity and the expected examination management of femtocells has also been supplied.

Spectrum partitioning and Frequency ALOHA (F-ALOHA) scheme were suggested [4]. By allocating orthogonal spectrum, it takes off interference between the macrocells and the femtocells. In the femtocells, each of the femtocell uses sub-channels in a random manner. An optimum spectrum share for the femtocells can be resolved. Nevertheless, this technique is based as to an ideal channel approach. Even though the spectrum is utilized adaptively, the full bands are not serviced for the macrocell.

For interference mitigation Dynamic Frequency Planning (DFP) algorithm was also a proposal [5].After separating the OFDMA network into various sectors, for every sector the quantity of sub-channels are calculated approximately to think

carefully about consumer band width demand.Interference between the sectors is evaluated when the same frequency is transmitted in the sectors.To minimize the overall network interference Optimization function is run.Nevertheless, this technique following a network structure which is centralized, therefore it is not suitable to manage femtocell for an individual owner.

FFR is the method to decrease the inter-cell interference in macrocell system, particularly for the cell edge consumers. In addition to it is beneficent to reach a goal the reuse factor of one. Under these circumstances, for the macro users the interference from the femtocells arrangement should be made smaller. So, we give more stress on the interference mitigation using FFR between the macrocell and femtocell.

1.4 OBJECTIVES

The main objectives of this thesis are:

1. Study of the various cellular structures.

2. Investigation of interference cancellation schemes in heterogeneous framework.

3. Proposing an interference management scheme to overcome the interference between femtocell and macrocell.

4. Evaluation of SINR, throughputs and outage probability in the heterogeneous network using the modified Fractional Frequency Reuse technique.

1.5 THESIS ORGANIZATION

The thesis is organized as follows:

Chapter 1: Introduction

Chapter 1 consists of objectives, motivation behind the project work and literature survey. This chapter gives brief idea about the Femtocells.

Chapter 2: LTE Femtocells-An Overview.

This chapter gives an overview of the femtocells and gives an introduction to its current standardization environment LTE and LTE Advanced which is also known as 3GPP Rel. 10.

Chapter 3: Interference Scenario in Heterogeneous Network.

This chapter gives the idea about interference and inter cell Interference Coordination (ICIC).And also how to control the interferences.

Chapter 4: Improved FFR Scheme for Interference Mitigation.

This chapter describes about Fractional Frequency Reuse, the types of Fractional Frequency Reuse and the reuse factor. And the system model and explains the Proposed Scheme. The mathematical expression for SINR for femtocell and macrocell respectively, channel gain, capacity of macro consumer, Overall throughput and outage probability are derived in this section. Also the Operational Algorithm.

Chapter 5: Simulation study, Result and Discussion.

In this chapter, we present the results of our simulation. The simulation is carried out in MATLAB and shows the plots for throughput of macro consumers in the center and edge, throughput of the macro and the femto consumers only in edge region, SINR CDF of FUEs and Outage probability of macro and femto consumers.

Chapter 6: Conclusion and Scope of Future Work

The final chapter presents the conclusions and also gives a brief description on how this work can be extended for further enhancements.

Chapter 2

LTE FEMTOCELLS-AN

OVERVIEW

2. LTE FEMTOCELLS-AN OVERVIEW

2.1 INTRODUCTION

Femtocells are small, low power, low cost, short ranged and plug and play cellular base stations that can be placed in homes and can be directly connected to the backhaul network through Internet Protocol (IP). By means of a network connection such as Asymmetric Digital Subscriber Line (ADSL) or through optical fiber this backhaul connection can be established. From the user's point of view, these are plug and play devices and no prior technical knowledge about the installation is required. However, these devices have to be purchased from the mobile network operator by anyone wishing to have it in their residences. The advantages of having a femtocell are that the indoor coverage can be enhanced, coverage holes can be eliminated and also the operators can provide a better service at the cell edge. A detailed description about the advantages and disadvantages of having a femtocell are given in the section 2.6. Femtocells are also called Femto base stations and it's a subset of a larger group called small cells.

Other types of base stations defined by 3GPP are "Macro base stations" for wide area coverage, medium range base stations called "Micro base stations" and local area base stations called "Pico base stations" for the coverage of large buildings like shopping malls and supermarkets. Figure 2.1 illustrates an overview of different types of cell with their size and capacity. But the main advantage of femtocells over picocells is their affordability for domestic use like Wi-Fi hotspots. There are currently three organizations working on the standardization of the femtocells, 3GPP, Small cell Forum and Broadband Forum. The industry and the universities are

also cooperating with them in the standardization process. As this thesis is based on the3GPP Rel. 10 standardization for femtocells, which is also called LTE Advanced (LTE-A), in the following section a brief introduction on LTE-A and its new features is given.
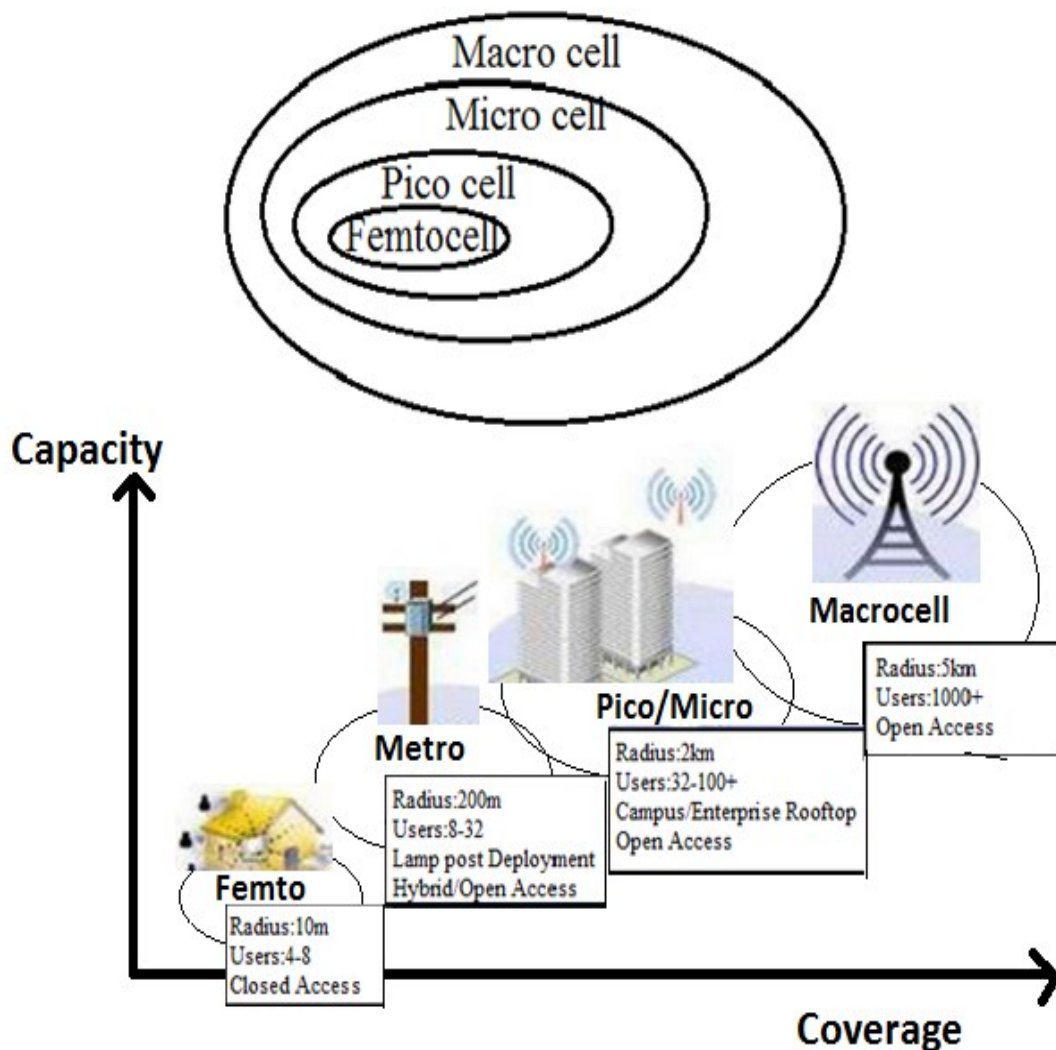

Figure 2.1 Types of cells

2.2 LONG TERM EVOLUTION (LTE)

LTE – Long Term Evolution is a technology standard for high-speed wireless communications through cellular networks. Large telecommunication companies around the world have integrated LTE into their networks by installing and

upgrading equipment on cell towers and in data centers. Devices with LTE support began appearing in 2010. Higher-end Smartphones starting with Apple iPhone 5 feature LTE support, as do many tablets with cellular network interfaces. Newer travel routers have also added LTE capability. PCs and other laptop or desktop computers generally do not offer LTE.

Customers using an LTE network experience greatly varying connection speeds depending on their provider and current network traffic conditions. Benchmark studies show LTE in the U.S. typically supports downloads (downlink) data rates between 5 and 50 Mbps with uplink (upload) rates between 1 and 20 Mbps. (The theoretical maximum data rate for standard LTE is 300 Mbps.) Technology called *LTE-Advanced* improves on standard LTE by adding new wireless transmission capabilities. LTE-Advanced supports a theoretical maximum data rate more than three times that of standard LTE, up to 1 Gbps, allowing customers to enjoy downloads at 100 Mbps or better. The networking industry recognizes LTE a 4G technology along with WiMax and *HSPA*. None of these qualified as 4G based on the original definition of the International Telecommunications Union (ITU) standards group, but in December, 2010 the ITU re-defined 4G to include them. While some marketing professionals and press have labelled LTE-Advanced as *5G*, no widely-approved definition of 5G exists to justify the claim.

LTE is broadly deployed in urban areas of North America and Europe. Many parts of Africa and some countries in South America lack LTE or similar high-speed wireless communication infrastructure. China has also been relatively slow to adopt LTE compared to other industrialized nations. Those living or traveling in rural areas is unlikely to find LTE service. Even in more populated areas, LTE

connectivity can prove unreliable when roaming, due to local gaps in service coverage. LTE communications work over Internet Protocol (IP) with no provision for analog data such as voice. Service providers normally configure their phones to switch between a different communication protocol for phone calls and LTE for data transfers.

However, several voices over IP (VoIP) technologies have been designed to extend LTE to support simultaneous voice and data traffic. Providers are expected to gradually phase these VoIP solutions their LTE networks in the coming years. Many customers have reported reduced battery life when enabling the LTE functions of their device. Battery drain can happen when a device receives a relatively weak LTE signal from the cell towers, effectively making the device work harder to maintain a stable connection. Battery life also decreases if a device maintains more than one wireless connection and switches between them, which can happen if a customer is roaming and changing from LTE to 3G service and back frequently. These battery life complications are not limited to LTE, but LTE can exacerbate them as the availability of service can be more limited than other types of cell communication. Battery issues should become a non-factor as the availability and reliability of LTE improves. LTE routers contain a built-in LTE broadband modem and enable local Wi-Fi and/or Ethernet devices to share the LTE connection. Note that LTE routers do not actually create a local LTE communications network within the home or local area. Similar security considerations apply to LTE as other IP networks. While no IP network is truly secure, LTE incorporates various network security features designed to protect data traffic.

LTE and Wi-Fi serve different purposes. Wi-Fi works best for servicing wireless local area networks while LTE works well for long-distance communications and roaming.

A person must first acquire an LTE client device and then sign up for service with an available provider. Especially outside the United States, only one provider may service some locales. Via a restriction called *locking*, some devices, primarily Smartphones, only work with one carrier even if others exist in that region. The best LTE networks offer a combination of wide coverage, high reliability, high performance, affordable prices and great customer service. Naturally no one service provider excels in every aspect. Some, like AT&T in the U.S., claim higher speed while others like Verizon tout their wider availability.

2.3 LTE-ADVANCED (LTE-A)

As mentioned in section 1.1 femtocells were first standardized in 2009 by the 3GPP. The initial standard formed parts of 3GPP's Release 8 and was interdependent with Broadband Forum continuation to its Technical Report-069 (TR-069) [22]. It was further enhanced by the introduction of heterogeneous networks for the co-channel deployment of macrocells and small cells in 3GPP Release 10. Instead of providing any enhancements to the macro base stations, the focus of LTE-A has been to come up with new technologies and features for LTE in order to provide several benefits for the users and the operators in terms of increased throughput, capacity and coverage.

2.4 TYPES OF FEMTOCELLS

There are three types of femtocells; Domestic, Enterprise and Metro-femtocell.

2.4.1 Domestic

It is typically a four channel Unit; it is capable of handling four voice calls and others many more attached to it to standby. It is basically used in the home.

2.4.2 Enterprise

It is typically a larger device capable of handling between 8 and 32 channels in the very heavily populated environment. it is basically used in the office.

2.4.3 Metro-femtocell

It is a new concept where the operator himself micro lies large number of femtocells to saturate particularly high traffic areas. This is particularly used at 4G and LTE technology.

2.5 HOW FEMTOCELLS WORK?

- ❑ If your cell phone is ringing and you answer it.
- ❑ If the phone is in close proximity to your home femtocell it will automatically route its voice transmission through the femtocell rather than through the nearest cell phone tower. Essentially, the femtocell is low-output cell tower that can rout voice data over short distances.
- ❑ The femtocell sends the voice data through your home cable or DSL modem, thus letting you save money on phone calls in your house by enabling you to send them over IP. As shown in the figure 2.2.
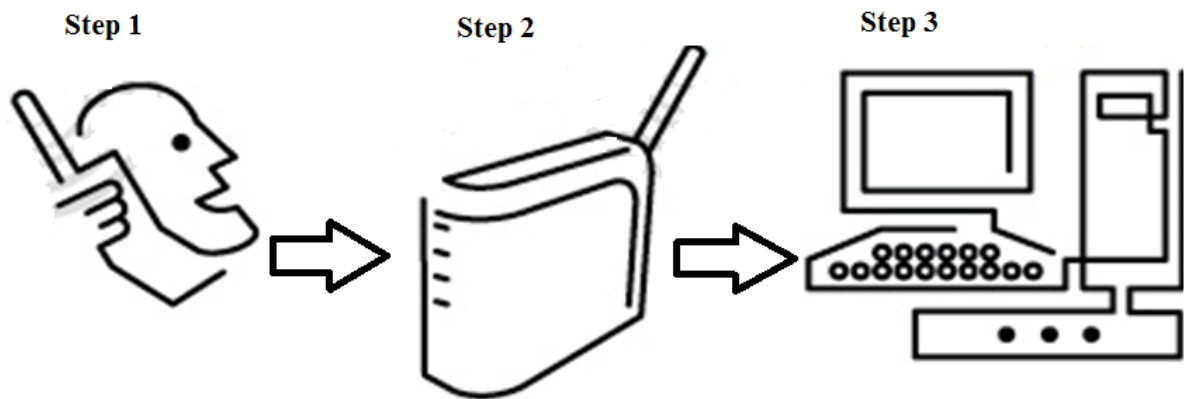
Figure 2.2 how femtocells work

- Fundamentally, they look for mobile phones as though they are normal mobile phone base station.

- They communicate in the same way, in same frequency using the same signal protocols and the same techniques.

- The mobile signal them self is when converted and sent by your broadband internet connection through to the Femto gateway. These connect to some hundred or thousand femtocell and convert the traffic into the same format this provided through a radio network controller for an outdoor cell site. It described in the figure 2.3.
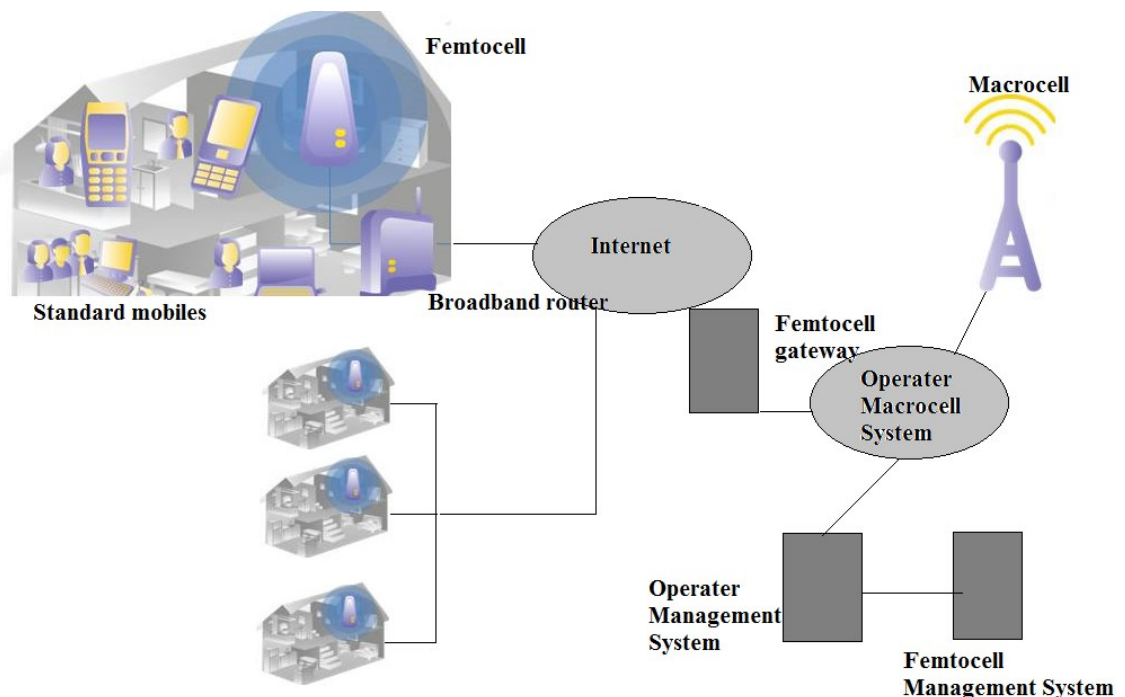
Figure 2.3 Architecture Femtocell

2.6 HETEROGENEOUS NETWORKS

A Heterogeneous network (HetNets) refers to the co-channel deployment of macrocells and small cells with the purpose of increasing the network capacity and coverage and also to remove coverage holes in indoor and outdoor areas. Small cells here mainly refer to picocells, femtocells, distributed antennas and relays. Picocells are well suited for shopping malls and large office buildings and they enhance the coverage in such places. Distributed antennas provide a uniform quality of service over the total coverage area, although they don't increase the capacity. They just share the same resources in the air interface in a large coverage area. The advantage of having distributed antennas is that the system can be upgraded easily by plugging in a new base station and distributed antennas simply extend the base station's antenna ports. The main advantage of femtocells over picocells and distributed antennas is that they do not need to be carefully planned. One of the most important aspects of heterogeneous networks is cross-layer interference which is more relevant to femtocells. Figure 2.4 illustrates an overview of a heterogeneous network comprising of all the above mentioned technologies.
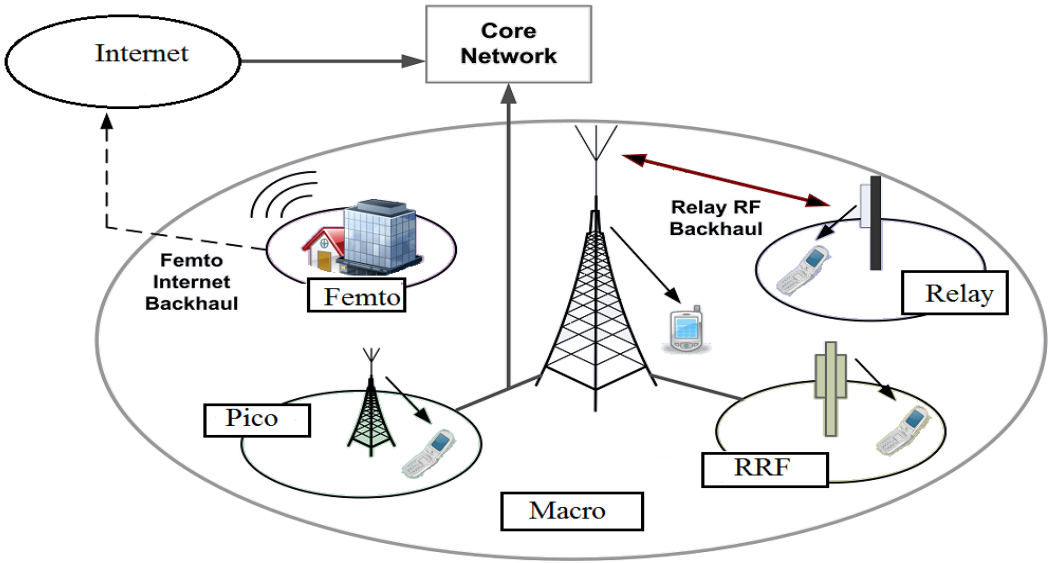
Figure 2.4 Heterogeneous network

2.7 ACCESS CONTROL

Open Access

It provides the service to anyone who passes nearer to the femto.

Closed access

A particular fixed number of home users are licensed to use the femto.

2.8 BENEFITS AND CHALLENGES FOR FEMTOCELLS

The femtocell concept provides advantages for both users and operators. But as any other newly introduced technology, it still has some issues that requires more research. Sections 2.8.1, 2.8.2 and 2.8.3 provide descriptions of the advantages and challenges of femtocells.

2.8.1 Advantages for users.

❑ Better indoor coverage: Wall penetration loss is a reason for the weakening of the signal which arrives from macrocells at indoors. Hence femtocells are a good low cost option. This is especially advantageous for the cell edge users as they receive further weakened signals from the macro cells due to path loss. Furthermore, interference from other macro eNodeBsare also high at the cell edge. If a HeNB is deployed in such a place with a reasonable transmit power a much better indoor coverage can be achieved.

❑ Lower transmission power at home: Both phone and the base station are now indoors, so they don't need to transmit with higher transmit powers. This is also beneficial for the health aspects of the users.

❑ Increased phone battery life: Since the HeNB receiver is at indoors, the UEs do not need to transmit at higher powers to achieve a better reception quality. Hence this increases phone's battery life.

❑ Since femtocells are plug and play devices, no technical knowledge is required by the users for installation and operation.

2.8.2 Advantages for operators

• Higher data rates: The users subscribed to the Mobile Network Operators (MNO) receive higher data rates from femtocells depending on their broadband connection through Local IP Access. The user traffic goes to the Internet Service Provider instead to the mobile operator network. Hence the MNO is able to provide better data rates for the users while offloading traffic from the macrocells.

• Increased Network capacity: Traffic offload from macrocells provides better network capacity and it also contributes for a slower growth of the backhaul costs.

• Increased Revenue: MNOs can place special tariffs for calls taken through femtocells. This also depends on the pricing policy of the operator.

2.8.3 The disadvantages of femtocells

• Interference: This is the main problem of using femtocells is that they interfere with the nearby macro users as well as other femtocell users if it's

under co-channel deployment. More about this will be elaborated in chapter 3 because mitigating this interference is the main focus of this thesis

- Quality of service: If the femtocell shares the home backhaul connection for data traffic with other equipment such as internet browsing and gaming consoles, this might affect the quality of service that it provides to the femto users. For example, if someone uses a video streaming application over the phone, the femtocell might struggle to reach the data rate requirement in a shared connection. Minimum requirements of the backhaul capacity must be expressed by the operator when the femto cells are bought. Some QoS differentiations as well as link reservation for femto traffic can be applied at the subscriber backhaul equipment.

- Spectrum accuracy: Femtocells are low cost devices. It is very difficult to generate a very accurate spectrum through low cost oscillators inside these devices. Hence 3GPP has also relaxed its standards for spectrum accuracy for femtocells from its later standards starting from Release 8

- Equipment location: Base stations usually find their location from the Global Positioning System (GPS). GPS most of the time is unable to find locations indoors due to low signal quality that occurs because of high wall penetration losses.

Chapter 3

INTERFERENCE SCENARIOS IN HETEROGENEOUS NETWORK

3. INTERFERENCE SCENARIOS IN HETEROGENEOUS NETWORK.

There are several interference scenarios involving HeNBs, Macro eNBs, MUEs and HUEs. When an eNodeB is interfering with a UE that is attached to another eNodeB in the downlink, it's called downlink interference and when a UE is interfering with an eNodeB's reception from another UE this is called uplink interference. When a HeNB interfere the users attached to another HeNB, this type of interference is called downlink co-layer interference. When a HeNB is interfering, the users attached to an eNodeB or vice versa, this is called downlink cross-layer interference. Figures 3.1 and 3.2 depict two scenarios of downlink co-layer and cross-layer interference respectively. Basically, there is two types of interference, these are Cross-tier and Co-tier interference.

- ❑ **Cross-tier**
    - ▪ Femto-Macro interference

        Interference between femtocells and Macro cells, working on the same frequency may interfere with each other.

- ❑ **Co-tier:**
    - ▪ Femto-Femto Interference

        Interference between neighboring femtocells may cause interference. UE transmitted signal reaching more than one femtocell.

The scenario of downlink cross-layer interference to MUEs discussed in this thesis is a result of several reasons. The first reason is that HeNBs are placed inside the coverage area of eNodeBs. The next reason is that both eNodeBs and HeNBs operate on the same frequencies which are also called co-channel deployment. Another cause is that, not only the HeNB provides coverage inside a house, but there is also a leakage of radiation to the outside which eventually results in interference.
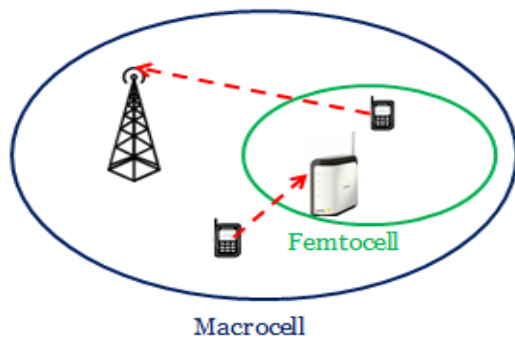
Figure 3.1 Cross-Tier   *Figure 3.2 Co-tier*
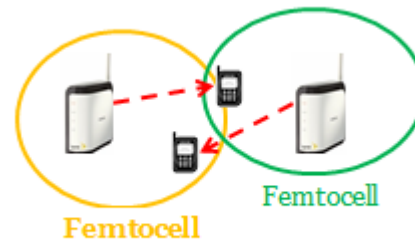
This leakage becomes severe if the walls have more open spaces or glass windows. Another reason for interference is that the HeNBs are more often configured in CSGs. This makes handover of a MUE to a HeNB impossible even if it gets the stronger signal from the HeNB.

3.1 INTERFERENCE CHALLENGE

Generally, the main problem of occurring interference due to two or many devices transmits nearer to each other. As is well known, the wireless network faces many interference problems. These are Inter Symbol Interference (ISI), which is happening when due to the delayed in multipath signal a symbol overlaps with the following symbols. Co Channel Interference (CCI) it occurs when a mobile transmits the data in the same channel which is already used in the nearby mobile. Co-tier and cross-tier interference which are already discuss in the above.

3.2 INTERFERENCE MITIGATION TECHNIQUES

Innovative interference mitigation techniques should be used with this novel type of sophisticated networks. Proposals to mitigate interference should take into consideration the nature of femtocells for a number of reasons:

1. Femtocells operate in licensed spectrum.

2. FBSs are installed and maintained by end users.

3. FBSs have limited computation and signalling power compared to regular outdoor BSs.

4. Femtocells are in most cases overlaid on macrocells.

Using these facts, we can derive a number of parameters that should be considered while designing femtocell interference mitigation solutions to ensure applicability:

Complexity requirements

Unlike the regular MBSs, the initial objective of a FBS is to provide better indoor voice and data services in a simple and cost effective way. This results in a small size FBS with limited computation and processing power. However, deployment issues necessitate avoiding complex algorithms for the mitigation purposes. By surveying the literature, we speculate that optimized algorithms based on Computational Intelligence (CI) like Genetic Algorithms (GAs), Simulated Annealing (SA), Neural Networks (NNs) and Game Theoritic-based algorithms will gain momentum in the context of research to provide stronger solutions.

Distributed Operation

In order to minimize decision delay, it is important that localized decisions are made, foregoing centralized processing, and the delays required for the two-way signalling.

Adaptability

Distributive is often linked to adaptability. Interference mitigation algorithms are expected to be highly adaptable to the surrounding environment since new FBSs can be deployed anywhere at any time, which will keep the current network infrastructure topology in a state of continuous change compared to the ordinary cellular network.

Scalability

 The projected density of deployment for femtocells also necessitates scalable solutions. To appreciate the minimal scale of deployment, the installation of a FBS per household should be assumed. This projected enormous volume entails highly scalable solutions.

One important aspect that should be also regarded is self-organization [34, 35]. The aforementioned zero-touch feature [24] mandates that a FBS be able to do self-configuration, self-optimization, and self-healing [9, 18]. The self-configuration characteristic mandates that a device, once powered up, starts collecting its configuration parameter and does configuration tasks, whether these parameters are hard-coded, on-chip, or reside on some server. On the other hand, self-optimization ensures that the device is always in a state of optimizing parameters such as signalling, power and frequency allocation to guarantee calm and effective communication. Finally, self-healing states that if certain communication failure occurs or degrading happens, the device should find fixes and apply them to continue operation. Self-organization is composed of all three, and is needed to ensure that the FBS unit can function on its own. Self-organization has been proposed at different phases of femtocell standardization. It can also be linked to adaptability because a FBS is in a continuous state of operation optimization. Signalling, power level and computations are examples of what can be optimized whilst the operation of a FBS.

3.2.1 Feasible Solutions

Interference mitigation solutions can be categorized against a number of criteria:

The operator managed vs FBS vendor managed. An operator managed solution affirms that the cellular provider coordinates the work of different femtocells and supplies them with parameters for operating interference mitigation solutions; whereas a FBS vendor managed (on-chip) solution requires that FBSs ship Pre-configured with certain interference mitigation out-of-the-box mechanisms regardless of the network they will be deployed as part of.

Locality

A localized solution runs at each femtocell, without the need for central coordination of calculations between FBSs. Localized techniques are more preferable to support scalability which requires that a FBS works on its own or in rare cases communicates with the surrounding FBSs. Conversely, network-wide techniques provide acceptable operation with generally less sophistication because they depend on specific central entities that aggregate information from groups of femtocells and use this information to compute solutions. Local versus network-wide solutions are also referred to as decentralized versus centralized solutions.

Application level

Categorization per application level describes the level of granularity at which the solution is applied, i.e., at the tier level or at the cell level. Solutions deployed at the coarse grained tier level tend to use durable, less or no changing parameters. In contrast, fine grained cell level solutions work on a much lower level and they need to be more adaptable and highly configurable. An example to show the difference between tier level and cell level is frequency planning in opposition to frequency allocation. In a multi-tier environment portions of the spectrum are split among tiers, without going deeper into the cells; this is a tier-level technique. On the other hand,

frequency allocation, where users within a cell are admitted frequency slots for transmission, is considered a cell-level technique.

3.3 INTERCELL INTERFERENCE COORDINATION

ICIC is the name used for the methods that are used to control interference in heterogeneous networks. Interference control is performed in both uplink and downlink. But here the priority is given to downlink interference control as the focus is on mitigating interference from HeNB to macro eNodeB user equipment. Interference control in the downlink can be basically achieved by two methods, power control and radio resource management. Downlink interference control methods can further be divided as control channel protection and data channel protection methods. The intention of this work is on data channel interference control methods.

Before activate any interference mitigating technique a HeNB first need to identify whether a user is interfered by its transmissions. For that purpose there are several types of measurements that can be collected. The following section gives some details about those measurement techniques.

3.3.1 HeNB Measurements

There are several measurements gathered by HeNBs which are important for the control of their interference and to maintain coverage. Some measurements are collected by the UEs that are attached to the HeNBs. Some measurement collections are performed by the downlink receiver of the HeNB. This is also called Network Listen Mode (NLM) of the HeNB. Other measurements are collected by the HeNB uplink receiver and this mode of measurement collection is called Radio Environment Measurement (REM) or HeNB sniffer.

Received Interference Power (RIP) when they are being configured or during normal operation. This measurement is useful for interference mitigation by the HeNB. If the RIP is above a certain predetermined level, this indicates that there's a MUE nearby and the HeNB must lower its power to avoid interference in the downlink.

3.3.2 Information Exchange

Other than the above mentioned measurements, HeNBs also gather information on interference control through information exchange with eNodeBs and other HeNBs. This option has the benefit of obtaining details about the uplink and downlink conditions in nearby eNodeBs and HeNBs when the HeNB configures its power and frequency resources. There are several ways to perform this information exchange with other eNodeBs.

- **Over the air information from eNB to HeNB**

    This scenario involves the transfer of vital data among eNodeB and HeNBs directly through the air interface. The advantage over direct information exchange is that it has a low latency. Direct information exchange among eNodeBs and HeNBs can also be used to coordinate scheduling as well. This helps in reducing interference to the UEs. But the main disadvantage is that over the air broadcasting can't be used when the eNodeB needs to send different types of data to different HeNBs. The eNodeB may also not be visible to HeNBs due to fading. This may result in occasional interference to the nearby macro users. When the information is read from the air interface downlink transmission is also halted which may affect the data rate of the user.

- **Over the air information from (H)eNB to HeNB via UE**

    In this method information is exchanged among HeNBs through UEs. This also has the advantage of low latency and can also be used to reduce

interference by sending scheduling information. This has the added advantage of being able to send different types of information to different HeNBs. But for proper operation there should be better links among HeNBs and UEs.

- **X2 based interface between eNB and HeNB, and between HeNBs**

  The X2 interface that exists among eNodeBs and HeNBs can also be used to transfer control information regarding interference management. This method is used currently for the exchange of such information among macro eNodeBs. But for interference control among eNodeBs and HeNBs, this might not be suitable because this link is having a high latency. The other reason is that the macro eNodeB has to send many messages to a larger number of HeNBs in its coverage area unlike in the macro-macro information exchange scenario. But information sent through this link can be accurate than information exchanged over the air interface because information exchanged over the air interface can have more packet drops due to fading. X2 being a wired link this problem does not occur. Hence, to reduce the complexity the procedures over the X2 interface can be limited to only sending Overload Indicator, High Interference Indicator and Relative Narrowband Transmit Power signals which require a higher latency among the eNodeB and HeNBs.

- **S1 based interface between eNB and HeNB, and between HeNBs**

  S1 interface exists between the E-UTRAN and the EPC or in other words, between the eNodeBs or HeNBs and the operator core network. This interface can also be used to exchange messages about interference management among eNodeBs and HeNBs. This also provides a higher

accuracy of data than the air interface similar to the X2 interface. Interference mitigation schemes that are using this scheme may also face the adverse effects of high latency.

3.4 INTERFERENCE COORDINATION

Interference coordination (also referred to as interference avoidance) is one of the most promising approaches to solve the problem of ICI in OFDMA systems, and has taken large concentration in 3GPP for LTE. The fundamental standard is to put into use few limits to the nonmaterial distribution in a relate technique between neighboring base stations. The categorization method can be classified into two types: resource management and resource scheduling, the coordination between base stations can be classified as static or adaptive.

Standard reuse and reuse partitioning schemes

LTE is designed to operate with an aggressive frequency reuse plan, with reuse-1 as an objective. Figure 3.3 (a) illustrates the frequency and power allocations in the reuse-1 course of action, where every frequency resource is ready for use in all places in every sector. The below side pictures in Figure 3.3 depict the mapping of power (P) to frequency (F), showing the frequency partitions; the upper pictures show the allocation of the frequency partitions to the sectors, including center and edge allocations in reuse partitioning schemes.

A conventional reuse scheme with a reuse factor greater than 1, such as reuse-3 or reuse-7, is the simplest interference coordination technique based on resource management. Figure 3.3 (b) illustrates the power and frequency configuration for a reuse-3 scheme. In reuse-3, each sector only gets one third of the bandwidth of the reuse-1 case, and the allocations are set up to be four-sided between right away neighboring sectors. This type of static resource management can avoid allocating

the same frequency resource in the adjacent sectors, leading to substantially lower interference.

(a) Reuse-1   (b) Reuse-2

(c) FFR   (d) SFR
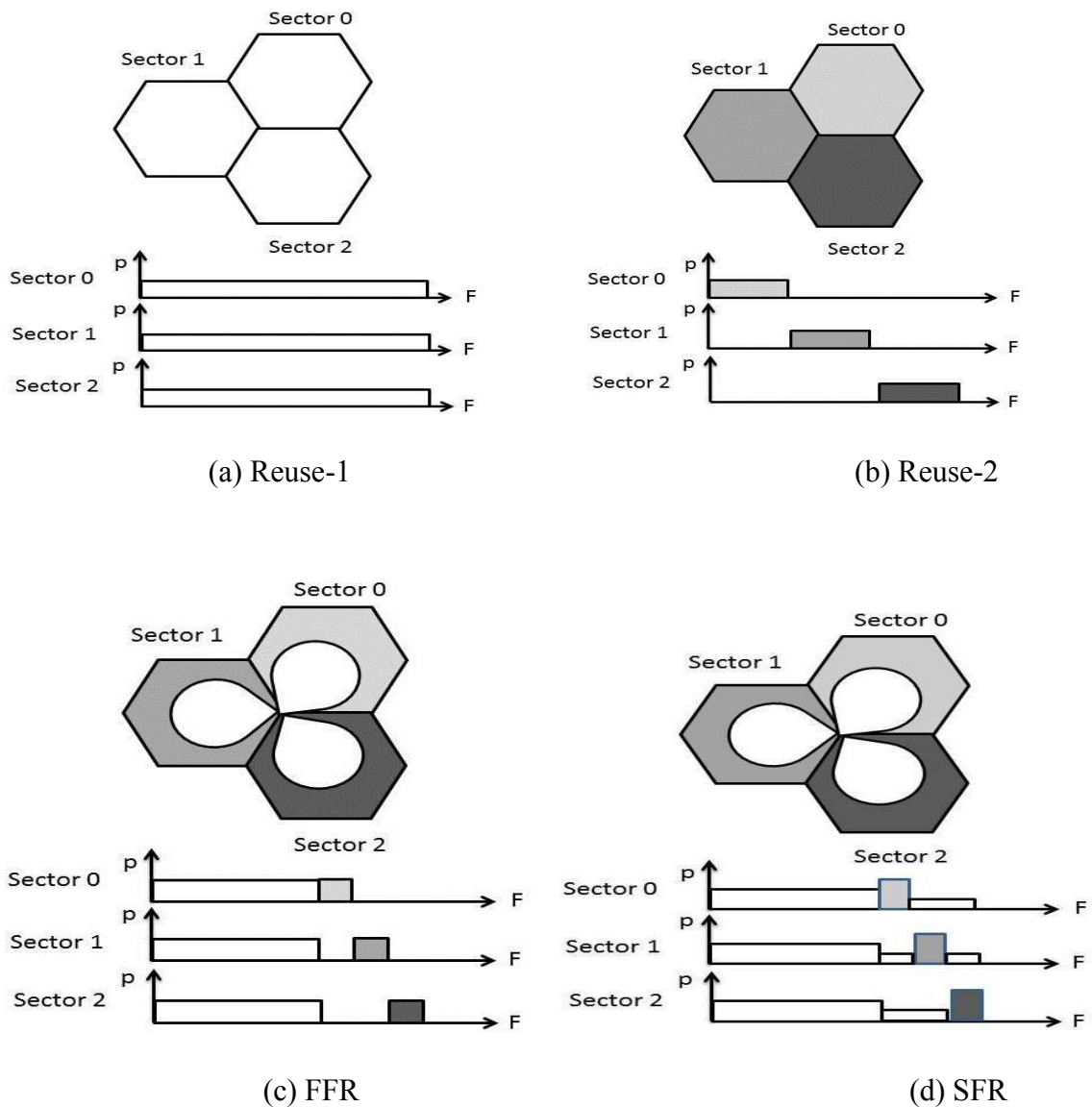
Figure 3.3 Standard reuse schemes.

Reuse partitioning is another type of resource management technique to mitigate ICI and improve sector edge performance. The essential idea is to partition the available frequency band in each sector into a reuse-1 band that is allocated to sector center users and a reuse-3 (or larger reuse) band allocated to sector edge users. Variants are possible, depending on whether the use of the edge bands of neighboring sectors is strictly prohibited in the reference sector (fractional frequency reuse (FFR), shown in

Figure 3.3 (c), or made available with reduced transmission power for sector center users (soft frequency reuse (SFR), shown in Figure 3.3 (d). If a user is deemed to be an edge user; only edge band resources can be allocated. Users in the center area can access both the center band and any unoccupied edge band resources. At FFR and SFR schemes, the edge band size is a valuable sketch limit, which can be exchanged done working and perpetuation intervention (static) or adaptive to traffic load variations in neighboring sectors. Furthermore, the power levels for the center and edge band can also be adjusted to pursue an improved overall system performance. These schemes may bring in some changes to the system design and implementation, and each scheme has its own advantages and disadvantages. In the static reuse schemes and reuse partitioning schemes, the spectrum allocations in each sector remain constant over time, and can be done off-line via network planning. Therefore, no inter-base-station communication is required. However, these schemes have the disadvantage that the available bandwidth in each sector is usually much less than that of reuse-1 scheme. In particular, it is extremely low in the standard reuse schemes; for example, only one third for reuse-3 compared to reuse-1 and even lower for schemes with a larger reuse factor. For the adaptive FFR/SFR schemes, some additional information exchange will be required via inter-base-station signaling in order to agree on the edge band size, possibly on a relatively slow time scale.

Chapter 4

IMPROVED FFR SCHEME FOR INTERFERENCE MITIGATION

4. IMPROVED FFR SCHEME FOR INTERFERENCE MITIGATION

4.1 FRACTIONAL FREQUENCY REUSE

In a conventional wireless network, macrocell base stations (M-BSs) are placed next to each other in a two dimensional plane such that the whole area gets the wireless coverage. In order to provide seamless coverage across the network, the coverage area of neighboring M-BSs are overlapped. In such a network layout, inter-cell interference occurs if all the macrocells use the whole system bandwidth. To avoid this interference, frequency reuse mechanism is used.

Figure 4.1 shows a typical macrocell network using the frequency reuse scheme. No two neighboring macrocells use the same frequency band in their coverage cells. The cell in the center uses frequency bands denoted by Freq. 3 which none of its neighboring six cells use. This pattern of frequency planning is repeated through the whole network. Figure 4.2 shows the repeated pattern of frequency reuse using 3, 4 and 7 cells multiplying over a segment of the macrocell network. Although frequency planning is an excellent way to avoid inter-cell interference between neighboring macrocells, it leads to an uneconomical usage of the system bandwidth.

As wireless frequency spectrum is a valuable resource, optimal utilization of the system bandwidth is of critical importance. The spectrum is becoming scarce with increasing number of wireless mobile devices. New ways to reuse the spectrum are being devised to meet the rising demand of the network bandwidth. Fractional Frequency Reuse (FFR) is a simple but useful technique to improve bandwidth usage across the network.
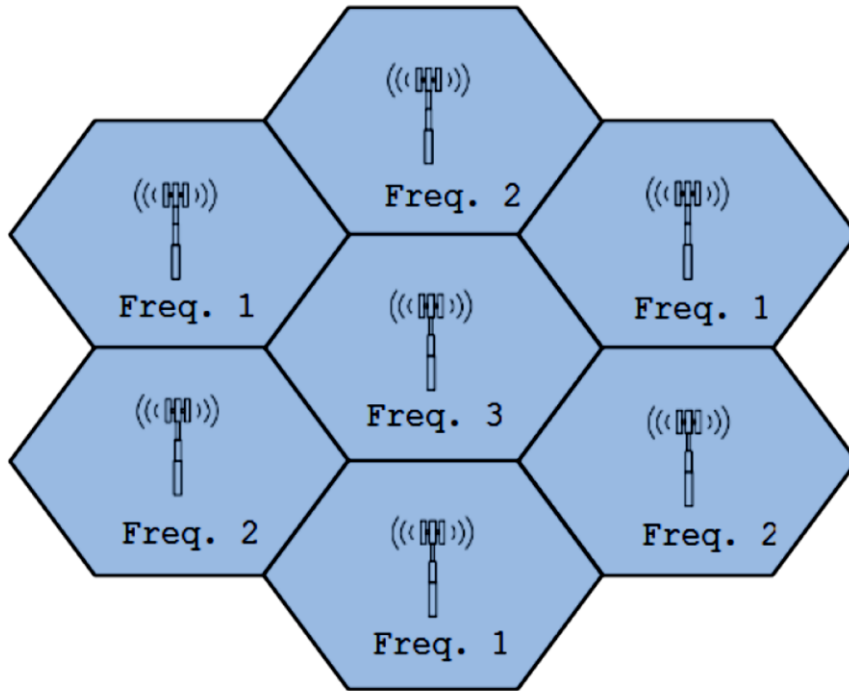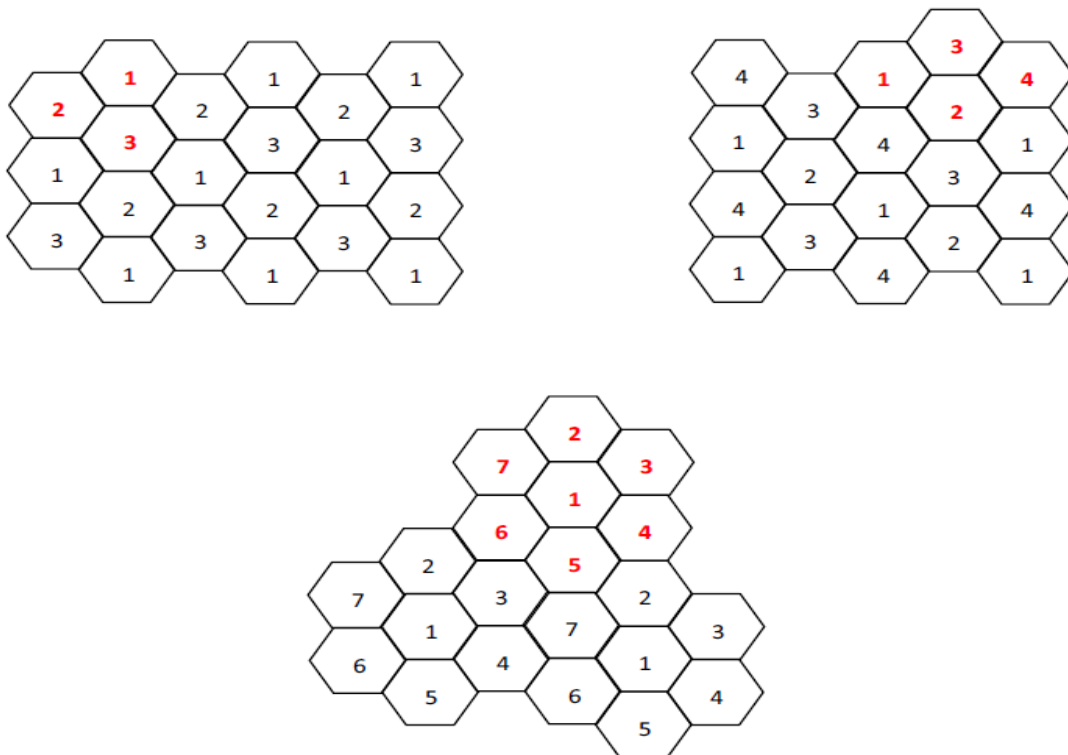
Figure 4.1 macrocell network

Figure 4.2 Repeated Pattern of Frequency Reuse

4.2 TYPES OF FFR SCHEMES

FFR is mainly divided into two types; Hard FFR and Soft FFR [18]. In hard FFR, the participating cells use distinct set of frequencies at the cell edge area while in the cell center they use only the frequency bands not used by any of the participating cells in their cell edges.

Soft FFR also uses distinct frequency sets at the cell edges of participating cells but unlike hard FFR, the cell centers use all the remaining frequency sets. The advantage of soft FFR is that it utilizes bandwidth more efficiently than hard FFR. But, it causes more inter cell interference as compared to hard FFR.

In the initial works they used NoFFR and FFR techniques. NoFFR, in this case only a single band of frequency is there. So interference is more.

And in the FFR-3 the full frequency band is divided equally into three sub band. These sub bands are assigned to the macro and femto users' randomly.This technique is better than NoFFR. Interference between the macro cells is decreased in this scheme. But there is Co channel interference between the femto and macro cell.which can be mitigating by our proposed scheme.In this case only three bands of frequency are used.

4.3 IMPLEMENTION OF THE PROPOSED SCHEME FOR FEMTOCELLS

In our proposed scheme for mitigating interference we use four frequency bands. Each cell is divided into two regions; center and edge region. We give more frequency band to the edge region femtocell. So that the interference is reduced in the edge region and the throughput is increased. So the performance is better. In this chapter we discuss about our work.

4.3.1 Analysis of Proposed Scheme

As shown in Figure 4.3 the FFR techniques are applied to each of the macrocell, for which we can easily decrease the interference among the adjacent cells and increase the throughput. Each hexagonal cell of the network is divided into two region one is inner (orange color) and the other is the outer region (colors yellow, blue and gray). The full frequency band is divided into two equal parts. The first part of this total frequency band is given to central zone with a reuse factor of one and the frequency band is denoted as I, while the rest frequency band is equally divided into three sub-bands, with a reuse factor of three and the frequency bands are denoted as J, K and L respectively. In Figure 4.3 it shows the division of the frequency band. In the outer region of a macrocell, if a femtocell is located, then we can reuse the sub band for the femto users which are used in the inner region. On the other hand, if in the inner region of the macrocell a femtocell is exist, and then the femtocell cannot reuse that sub-band which was already assigned to the users which are in cell edge of that macrocell. In each case the transmit power of the base station is the reason. The Inner cell users are always closer to the base station that means we need less transmitting power. As they always getting good coverage from the nearer base station. While for the cell edge users, we need more transmitting power from the base station. In the edge region the receiving power is less so the coverage is very bad and the interference is more. So our aim is to give good coverage to the edge region and reduce interference using FFR scheme.
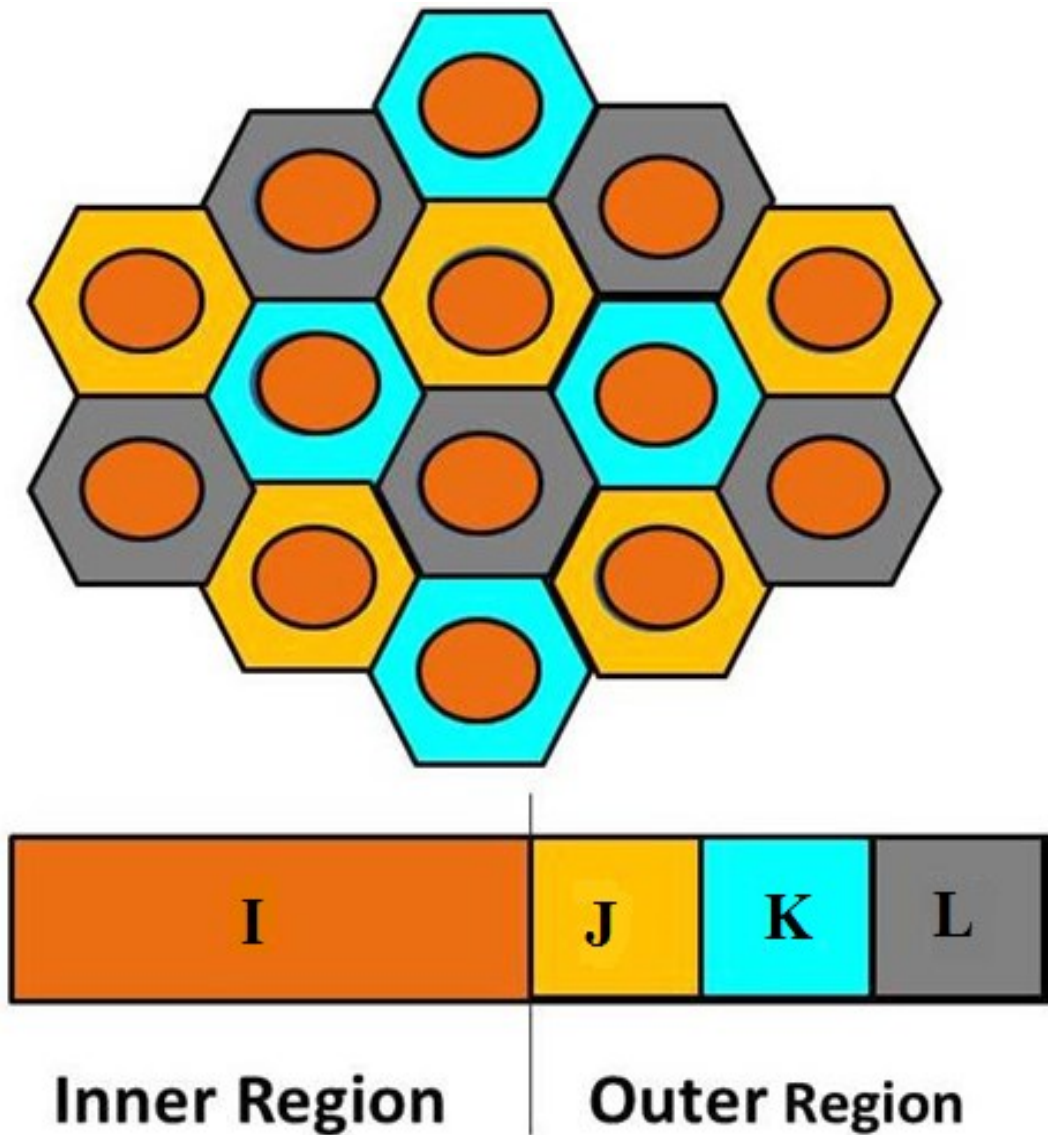
Figure 4.3 Frequency Band

For example, in the Figure 4.3, if in the outer zone of the central cell the femtocell is operating with the colour orange and yellow, then it cannot use not only the sub-bands Land K of colour blue and grey, respectively. Because those are given to the outer zones of the adjacent cells and also we cannot give the sub-band I with orange colour even though it is already applied in this macrocell. In these scenarios, the interference from the femtocell to the macrocell and vice versa will be mitigating.

In figure 4.4 it describe the distribution of frequency sub bands for the full band into the macrocell and femtocell. The coverage of macrocell is broken in to two parts,

one is center zone and the other is edge region, containing three sectors per each, In center zone it is indicated by Zl, Z2, Z3, and in the edge zone it is indicated by RI, R2, R3. The entire frequency band separates into two equal parts first part is for reuse factor 1, and the next part is again divided into 3 equal parts, all are denoted as I, J, K and L. In the center zone reuse factor 1 is used. And in the edge region reuse factor 3 is used. The sub-band I is applied to the center region (Zl, Z2, andZ3), and the sub-bands J, K and L used in the Rl, R2 andR3 regions.

Below this situation, femtocell selects those sub-bands, which are not applied in macrocell sub-area. Particularly, femtocell which is in center region has to exclude the sub band which is already used in the edge zone of that particular sector. For example, if a femtocell is in the area Rl, it can use only the sub-bands I, K, or L. and the sub band B is for the macrocell. Now in the center zone Z1 if a femtocell is located, then the sub-band K and L are used.

Due to the typical feature of OFDMA [15], macrocell is intervening by inter-cell, and by the FFR that interference is mitigated. Femto cell applies the dissimilar sub-band to prevent interference from macrocell. The Sub-band is reused in the coverage of macrocell as much as possible. As femtocell have very less transmitting power. For that reason, the interference among macrocell and femtocell is considerably prevented. In order to increase the throughput of the consumers which are in the edge region, we allocated more number of sub carrier to the femtocells in that region. In our scheme we provided two sub bands to the femto users which are in the center region. And three sub bands to the femtocells which are in the edge region. That's why our performance is better than NoFFR and FFR-3.

This same technique is also applied in the other two sectors. Likewise we divide all the cells in same manner one is center zone and the other is edge zone. In every cell

the performance is good. So the overall network performance is increases we get good coverage in the all the place. The indoor coverage is increases and the interference is decreases.
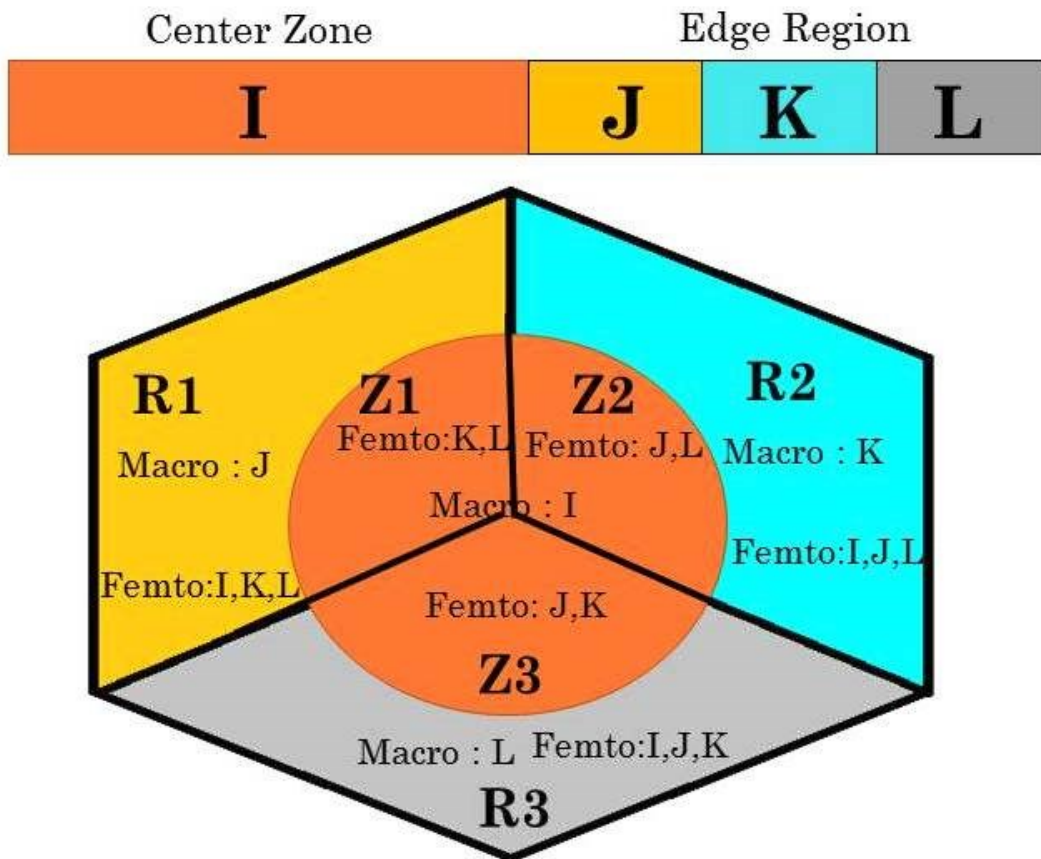
Figure 4.4 Proposed interference management scheme using FFR

4.4 MATHEMATICAL ANALYSIS

4.4.1 Calculation for SINR

$$SINR = \frac{Power\ of\ the\ incoming\ singnal}{Noise\ Power + Interfernece\ Power}$$

We formulate system throughput and downlink signal to the Interference and Noise Ratio (SINR). The total network is divided into 19 numbers of macrocells, and the femtocells are randomly assigned. There is interference between the macro users with the neighboring 18 macrocells and also with the adjacent femtocells.

Here we calculate the signal to the Interference and Noise Ratio (SINR) for both femto and macro users. Then we calculate Channel Gain, Capacity and overall throughput.

The received SINR of the macro consumer m on the sub-carrier c can be signified as [21].

$$SINR_{m,c} = \frac{P_{M,c}G_{m,M,c}}{N_0 W + \sum\limits_{M'} P_{M',c}G_{m,M',c} + \sum\limits_{F} P_{F,c}G_{m,F,c}}$$

(4.4.1.1)

Where,

1. $P_{M,c}$ is transmitting power of serving macrocell M.

2. $P_{M',c}$ is transmitting power of neighbouring macrocell M' on sub-carrier c.

3. $G_{m,M,c}$ is channel gain between the macro consumer m and on sub-carrier c serving macrocell M.

4. $G_{m,M',c}$ is the Channel gains from neighbouring macrocells.

5. $P_{F,c}$ is transmitting power of neighbouring femtocell F on sub-carrier c.

6. $G_{m,F,c}$ is channel gain between macro consumer m and neighbouring femtocell F on the sub-carrier c.

7. N_0 is the white noise power spectral density.

8. W is the sub-carrier spacing.

In case of a femto consumer, the femtocell interfered by the all 19 macrocells and close femtocells. Similarly, received SINR of a femto consumer f on sub-carrier c can be given by [21]

$$SINR_{f,c} = \frac{P_{F,c}G_{m,F,c}}{N_0 W + \sum\limits_{M} P_{M,c}G_{f,M,c} + \sum\limits_{F'} P_{F',c}G_{f,F',c}}$$

(4.4.1.2)

The channel gain G mainly influenced by path loss, which is not equal for outdoor and indoor. The path loss models that are being used in this thesis are based on the log distance path loss model specified by 3GPP [30].For outdoor the path loss is

$$PL_{outdoor} = 28 + 35\log_{10}(d)\,\text{dB}$$

(4.4.1.3)

Where d is the interval between the users to a base station in meters.

Alternatively, for indoor model the path loss is

$$PL_{indoor} = 28 + 35\log_{10}(d) + L_{walls}\ \text{dB}$$

(4.4.1.4)

Where L_{walls} is 7 dB for light internal, 10 dB for internal and15 dB for external walls.

So, the channel gain G can be signified as [29]

$$G = 10^{-(PL/10)}$$

(4.4.1.5)

The practical capacity of macro consumer m on sub-carrier c can be given by [21]

$$K_{m,c} = W.\log_2(1 + \alpha\, SINR_{m,c})$$

(4.4.1.6)

α is a constant for the target Bit Error Rate (BER), and give a description by

$$\alpha = -1.5/\ln(5BER)$$

(4.4.1.7)

Here, we set BER to 10^{-6}.

4.4.2 Calculation for Throughput

If the throughput is more than the data rate is more. We get better coverage and the interference is reduced. Throughput is usually measured in bits per second. Throughput is finding out by calculating the capacity of macro users and the sub carrier assigned to the macro users.

The overall throughput of serving macrocell M can signify as [24]

$$T_M = \sum_m \sum_c \beta_{m,c} K_{m,c}$$

(4.4.2.1)

Where, $\beta_{m,c}$ notifies the sub-carrier assignment for macro consumers.

When $\beta_{m,c}$ = 1, the sub-carrier c is select and give a responsibility to macro consumer m. alternatively, $\beta_{m,c}$ = 0. From the typical feature of the OFDMA system, each sub-carrier is assigned only one macro consumer in a macrocell in each time place. It implies that $\sum_{m=1}^{N_m} \beta_{m,c} = 1$. Where N_m is the number of macro consumers in a macrocell.

Similarly expression for femto consumers connected to the useful capacity and overall throughput is attainable other than $\sum_{f=1}^{N_f} \beta_{f,c} = 3$. N_f is the number of femto consumers in a macrocell. This indicates that the proposed scheme in a macrocell reuses the full frequency band three times.

4.4.3 Calculation for Outage Probability

Out probability affects the performance. It affects the data rate and throughput. To find out the outage probability we need a threshold value. If the outage probability is less, then the throughput is increases, if the throughput is increases then the data rate increases. That means performance is increases. If the performance is better that means the interference is less. So if outage probability is low then the interference is low. That's why we find out outage probability in this scheme.

Here we evaluate this proposed technique in conditions of throughput utilizing SINR threshold in the distance of 0 to 25 dB. We also think about closing on the

accomplishment of work for the cell edge consumers. The outage probability is resolute though SINR level of a sub-carrier does not to go beyond in quantity of the indicate threshold. The outage probability P_{out} is given by [23]

$$P_{out} = \frac{\sum_u \sum_c \delta_{u,c}.SINR_{u,c}}{\sum_u \sum_c \beta_{u,c}.SINR_{u,c}}$$

(4.4.3.1)

Where, $\delta_{u,c}$ indicates failed sub-carrier assignment for user u on sub-carrier c.

If $\delta_{u,c}$ =1, the SINR of that sub-carrier is under the SINR threshold ($SINR_{u,c}$ < $SINR_{threshold}$). So, the ratio between the number of sub-carriers under the SINR threshold and the number of the total sub-carriers is the outage probability.

4.4.4 Calculation for Cumulative Distribution function

It explains a statistical distribution. At each possible outcome, it has the value, of the probability of receiving that outcome or a lower one. If we have a random value then to find the nature of those value we go for cumulative distribution function (CDF).From CDF we can easily study the nature of those random value. In our scheme SINR is the random value.

$$F_x(x) = \int_{-\infty}^{x} f_x(t)dt$$

(4.4.4.1)

4.5 STEPS FOLLOWED TO IMPLEMENT THE PROPOSED SCHEME

1. The macro users are divided among the sub-carriers, according to the FFR as shown in the Figure 4.2.

2. The cell is divided in to two zones one is center zone and the other is edge zone.

3. The center zone and the three sectored edge domain use the divided frequency sub band.

4. Under this condition, when femtocell turns on, it senses the neighbouring macrocell signals.

5. The Received Signal Strength Indication (RSSI) principles are distinguished for every sub-band I, J, K, and L. When RSSI of the sub-band I is strong, in the center zone the femtocell is located.

6. If sub-band J signal is powerful, the femtocell activity is zoning Z1. The femtocell selects sub-carriers from sub-band K and L. It excludes the sub-band I and J, whose signal power is powerful because these are used by the macro users. This is similar for zoneZ2 and Z3.

7. On the other hand, the femto cell is placed physically on location in the edge region, if RSSI of the sub-band I is weak. Additionally, if sub-band J signal is strong, the femtocell position is the region R1.

8. The sub-carriers from the sub-band I, K, and L are selected by the femtocell. The sub-band J is excluded on account of its RSSI is high.

9. A similar scheme is possible for the region R2 and R3.

Chapter 5

RESULTS AND DISCUSSION

5. RESULTS AND DISCUSSION

In this chapter we describe the simulation procedure and environment were designed so as to follow the system architecture, frequency bands, planning model, network layout and SINR generation models. Simulation assumptions and general simulation parameters are listed in detail. Evaluation metrics and their respective simulation scenarios are also presented, along with scenario specific parameters. Simulation results and complexity analysis are shown towards the end of this chapter.

5.1 NETWORK ARCHITECTURE AND FREQUENCY PLANNING MODEL.

For the simulation environment figure 5.1 shows the network layout. The layout consists of

- The cell which is divided in to two zones one is center zone and the other is edge zone.

- Center zone naming as Z1, Z2, Z3 and edge zone naming as R1, R2, R3.

- The zones consist of macrocells and femtocells.

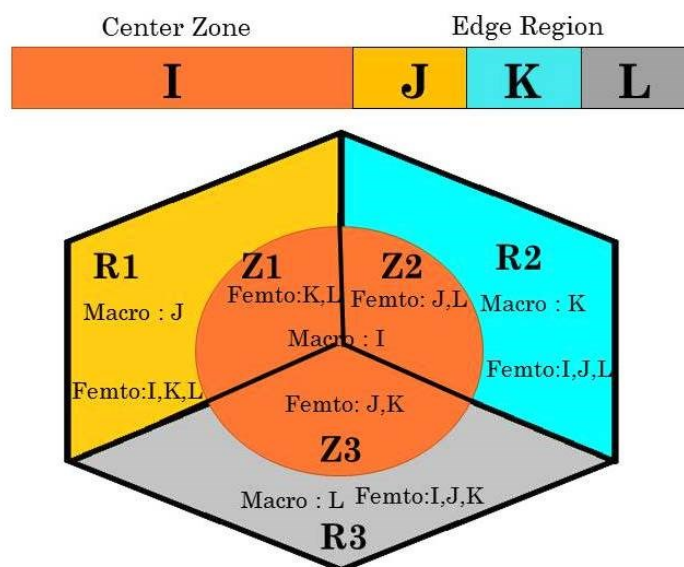- The cell is also divided in to three sectors.

Figure 5.1 frequency band

The available spectrum is divided in to two equal parts. First parts are used for center zone with a reuse factor of 1, while the other part is sub divided in to three parts and used in the edge zone with reuse factor of 3. The total four sub bands so obtained are denoted as I, J, K and L (denoted by colors orange, yellow, blue and gray). The band I is used in the center zone and the rest are in the edge zone as shown in the figure 5.1.

5.2 SCENARIOS AND ENVIRONMENTS

The proposed technique is compared with several existing techniques. In FFR-3 frequency bands are allocated to the macro and femto users randomly. In conditions, when FFR is not adopted the frequency bands of consumers are fixed it is called NoFFR. The total available sub carriers are divided into 3 sub-groups in FFR-3 technique. For evaluating the performance of our proposed scheme we compared our data with the FFR-3 and NoFFR techniques. We found out the SINRs for femtocell and macrocell. Then with respect to SINR we calculated the throughput.

5.2.1 Simulation study

This section illustrates the type of parameters and there values that are configured for the simulations. Simulations are done with the assumption that network consists 19 macrocells with two-tier structure. In order to provide adequate variation in the simulation environment we have varied the number of femtocells from 50 to 300. In the overall network the macro users and the femto users were assumed to be randomly distributed. In center zone transmitting power was kept at 15W and in the

edge zone for macro base station at 22W. For all the femto base stations the transmitting power is 20mW.

Table 1 indicates facial characteristics are given a rundown. The quantity columns mean the quantity of applied sub-carriers means by the sub-carrier task limit β. Table 2 states the simulation limits. In OFDMA technology every base stations are worked. Here we change the femtocells from 50 to 300 in each of the coverage of the macrocell for changing the simulation atmosphere. In the overall network the macro and femto consumers are randomly distributed. In each scheme the designated range of available sub-carriers are randomly distributed to the macro and femto consumers. When FFR is applied, the macro user uses a part of the frequency bands given to the central zone and the rest is given to the edge region. Three sectored antennas and an omnidirectional antenna are set up on a macro base station and with 15W transmit power for center zone and with 22 W for the edge region.

Table 1.Concise of projected and contrasting course of actions

Schemes	Macro consumer		Femto consumer	
	Frequency	Quantity	Frequency	Quantity
Proposed	FFR	1	Divide center and edges (Figure 1)	3
FFR-3	FFR		Random	
NoFFR	Random		Random	
Note: quantity column indicates the value of $\sum_{m=1}^{N_m}\beta_{m,c}$ and $\sum_{f=1}^{N_f}\beta_{f,c}$ for macro and femto users, respectively.				

Table 2. Simulation Parameters

Parameters	Values	
	Macro	Femto
No of cells	19	50-300/macro
Cell coverage	280m	30m
BS transmits power	FFR: 15,22 W w/oFFR: 20 W	20mW
Bandwidth of Channel	5 MHz	
FFTsize	512	
No of sub- carriers occupied	300	
Sub-carrier spacing	15 kHz	
White noise power density	-174 dBm/Hz	
Size of the central zone	0.63 of macro coverage	
Channel model (Path loss, *PL)*	$PL_{outdoor} = 28+35log_{10}(d)$ $PL_{indoor} = 38.5+20log_{10}(d)+L_{walls}$ $L_{walls}= 7$ dB, if d in (0,10] $L_{walls}= 10$ dB, if d in (l0,20] $L_{walls}= 15$ dB, if d in (20,30]	

On the other hand, 20W is the transmitting power of a macro base station; it is used in case FFR is not used by the macro consumer. 20mW transmitting power limit is the used by all the femtocells. Different types of channel models are applied for outdoor and indoor scenarios, where dominant factor is path loss. After that, received SINR principles are found out for every consumer and every sub-carrier in the downlink. Applying this principle, the throughput for 19 cells at the central serving macrocell, the outage probability is figured out.

5.3 SIMULATION RESULTS

MATLAB simulation software was used for the computer simulation. In figure 5.2, it demonstrates that as the number of femtocells increase the throughput of macro consumer situated in the macrocell coverage decreases. In the suggested techniques,

at every location the femto consumers can get the sub-carriers which are not used by macro consumers. Therefore, we can greatly prevent the interference among the macro consumers and femtocells. Femtocell users effect to macro consumers is minimal than the compared techniques. But in the FFR-3 and NoFFR techniques, they assigned random sub carriers to the Femto consumers, regardless of the sub carriers are used by the macro user. Therefore, the macro consumer and the femto consumers may use sub-carriers very nearer to one another thus cause interference. Due to this, interference between the macro consumers and the femto consumer is bigger than the proposed scheme. Nevertheless, the proposed scheme avoids this interference at minimal degradation. It is observed from the graph that due to mitigation of interference in the femtocells and macrocell the throughput is increased for all the macro users using the proposed scheme. It shows that when the numbers of femtocell is 50 at that time for noFFR throughput is 8.8Mbps, and for FFR-3 throughput is at 9Mbps and in the proposed scheme, it is rises to 11.5Mbps. So the improvement is about 2.5Mbps. Although with the increase in the number of femtocells throughput decreases but still it is better than FFR-3 and NoFFR.

As shown in the figure 5.2, in the NoFFR scheme the interference is more as same frequency band is used. Same frequency is reused by each sector, so large inter-cell interference. And in figure 5.3, FFR-3 uses three frequency bands randomly divided into the sectors. Same frequency is reused in every 3 sectors, so there is low inter-cell interference and hence better performance than NoFFR. But in our proposed scheme in figure 5.3, we have a different frequency band in the edge region reduces the interference much efficiently.
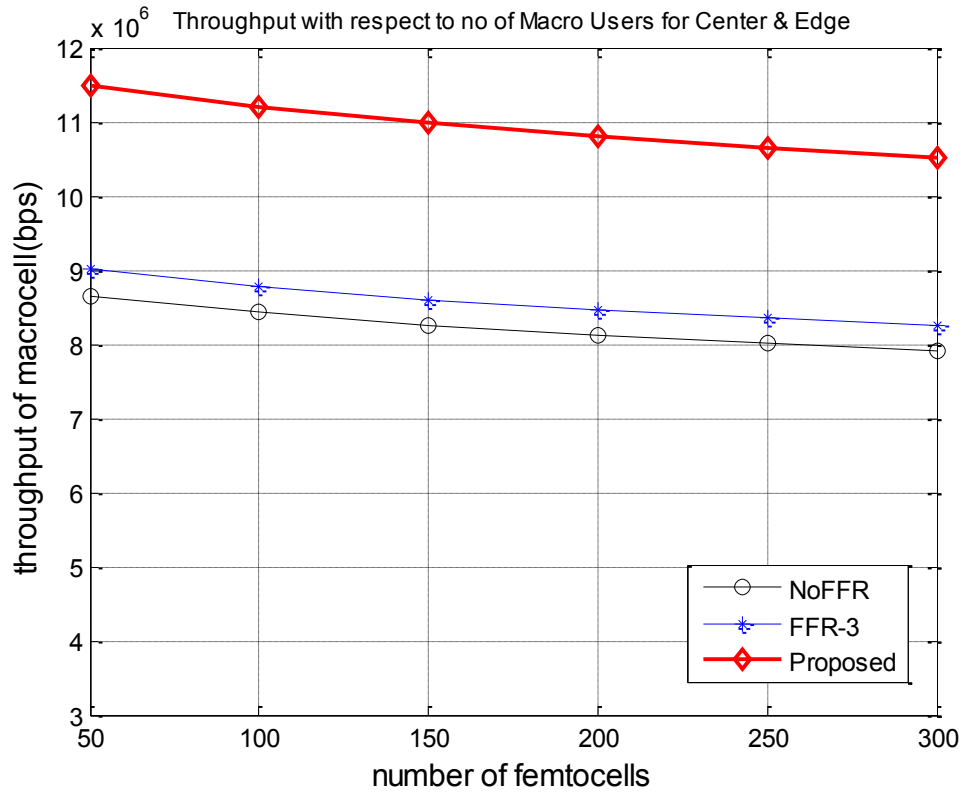
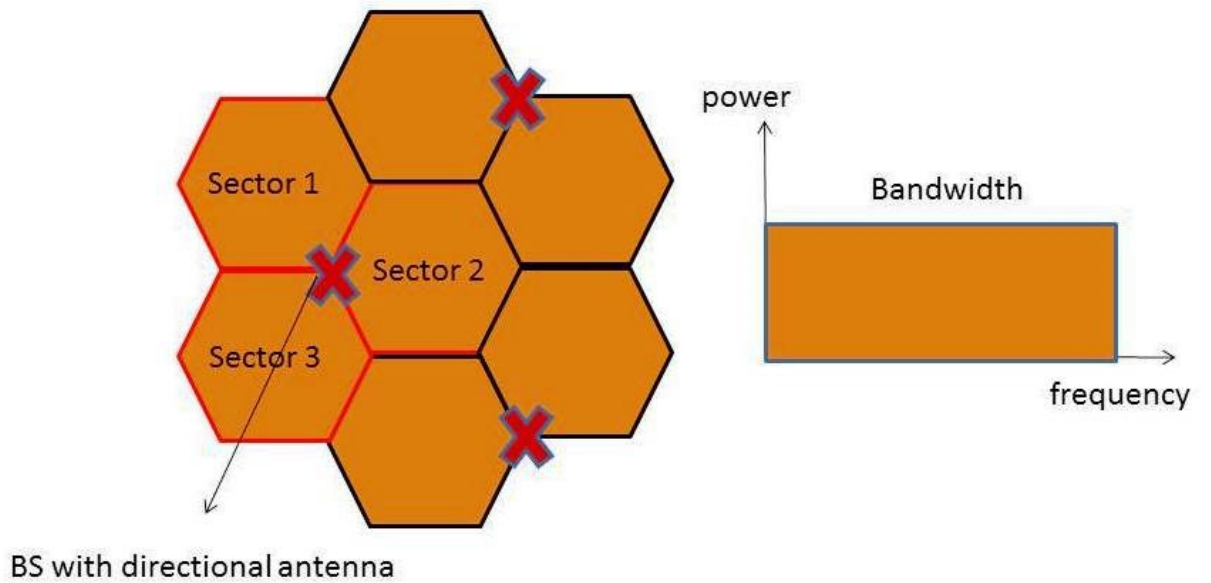Figure 5.2 Throughput of macro consumers in the center and edge, as the number of femtocells increases.

NoFFR

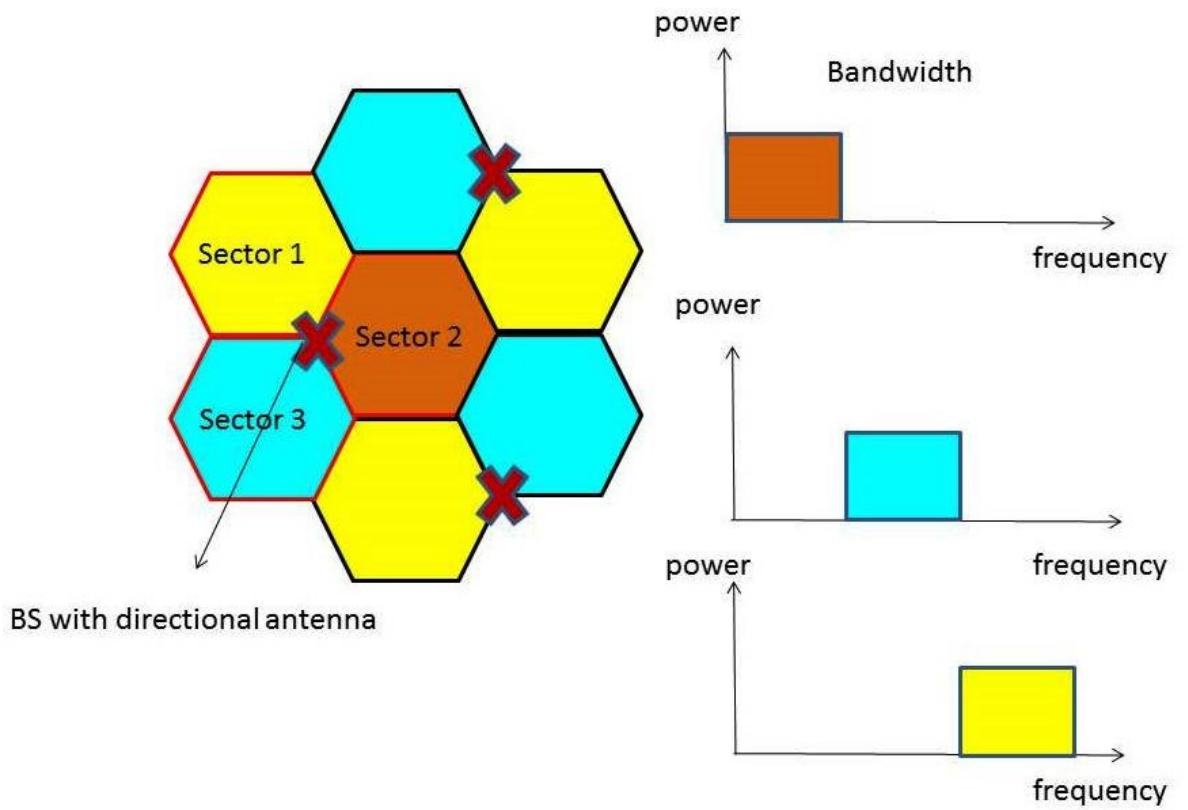
Figure 5.3 NoFFR

FFR-3

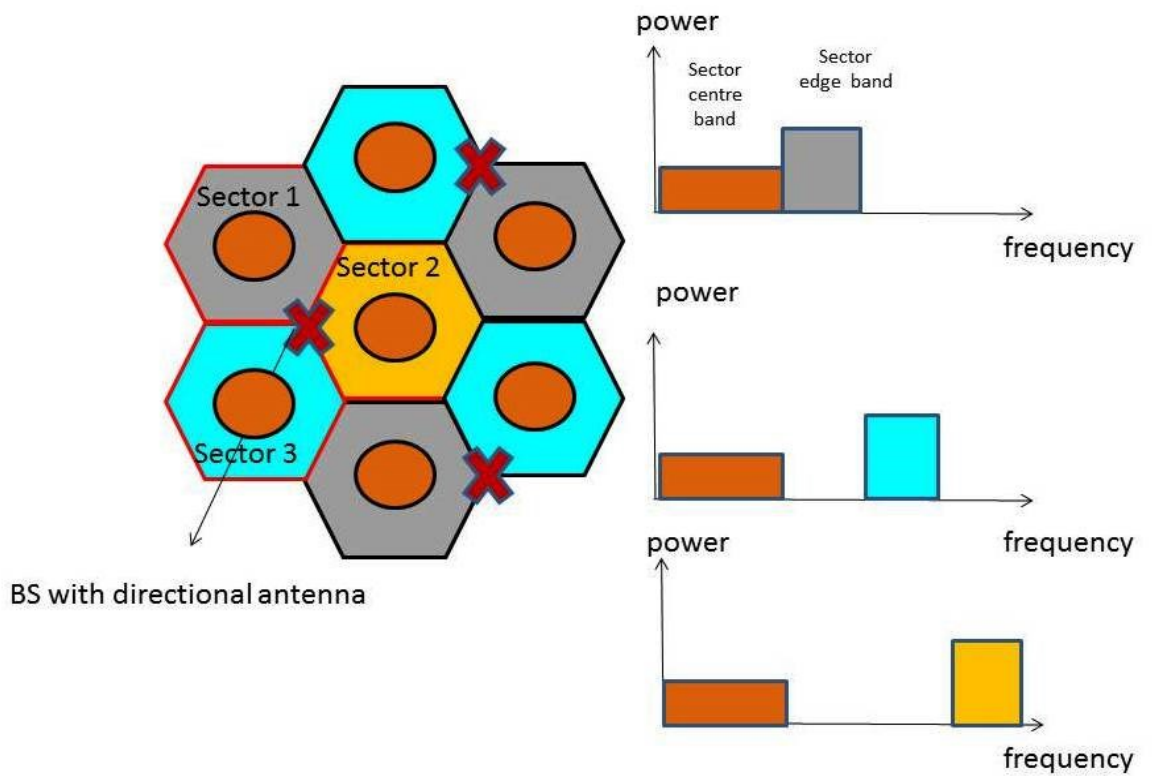Figure 5.4 FFR-3

Proposed Scheme

Figure 5.5 Proposed Scheme

In figure 5.6, it depicts the total users' throughput situated at the edge region. The performance in the edge region degrades, due to inter cell interference in the network. In the suggested techniques, we are allocating more number of subcarriers to the femtocells which are in the edge region, due to which edge region throughput is increased.
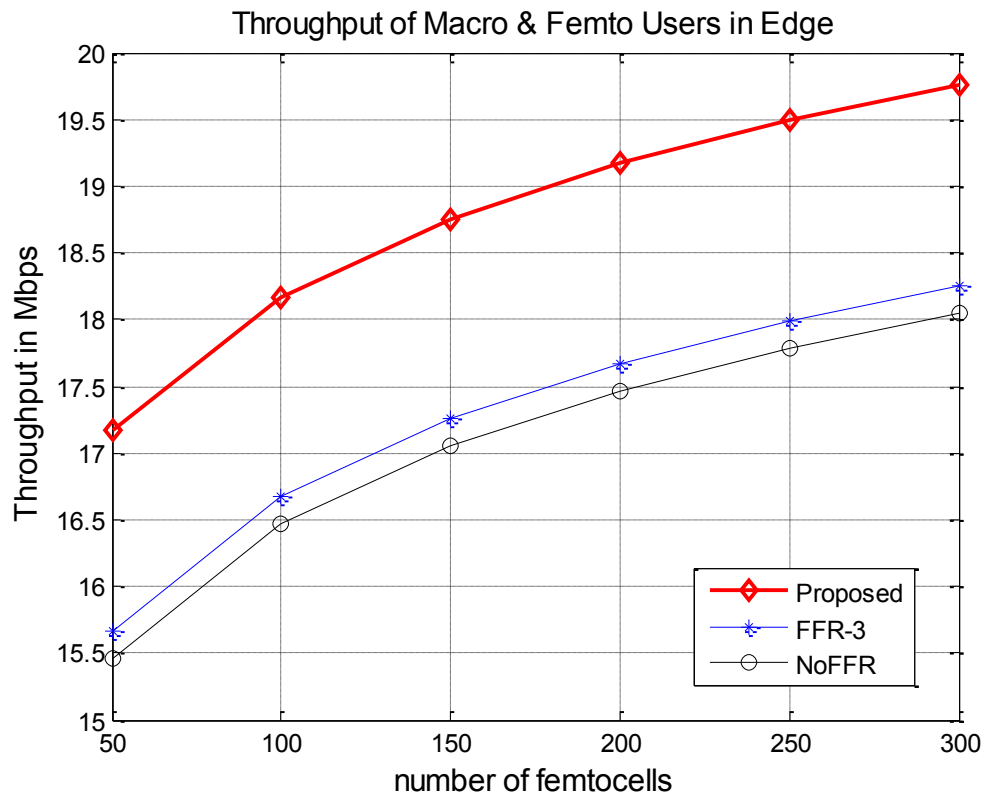

Figure5.6. Throughput of the macro and the femto consumers only in edge region as number of femtocells increases.

The existing schemes assign sub-carriers irrespective of the user location, which may be center zone or edge region. That is why the throughput is less than the proposed scheme. It may also be noted that, FFR-3 scheme demonstrates a better throughput compared to NoFFR scheme, since it decreases interference by using FFR to the macro consumers. The gains of the proposed scheme are 27% and 47% at an average, compared to the FFR-3 scheme and NoFFR, respectively. It is evitable from the graph that with increase of number of femtocells from 50 to 300 the throughput

also increases. When the number of femtocells is 300 NoFFR throughput is 18Mbps, similarly for FFR-3 it is 18.25Mbps but in our scheme it is increases to 19.75Mbps which is much better than the compared schemes. This is possible by increasing the number of frequency bands in the femtocells in the edge region, so that the interference is less and the throughput is increased.

Figure 5.7 demonstrates the SINR Cumulative Distribution Function (CDF) for femtocell users (FUEs) with the number of femtocells at 50. It can be seen that the link performance of FUEs in the low SINR region as well as in the high SINR region is efficiently enhanced by the use of the proposed technique. It is worthwhile to mention here that, the suggested techniques significantly protects near macrocell users from interference caused by femtocell base stations as compared to the case of NoFFR and FFR-3 due to increase in the number of frequency bands in the edge region.
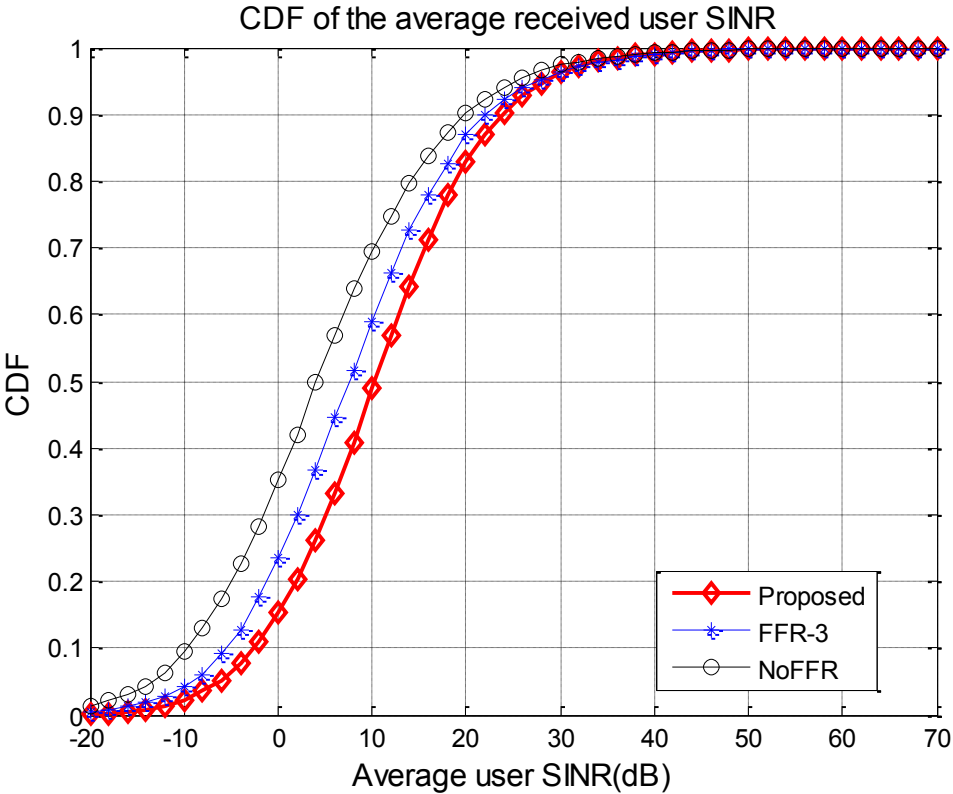

Figure 5.7.SINR CDF of FUEs

CDF describes a statistical distribution whose value at each possible outcome is the probability of receiving that outcome or a lower one.

If we consider the point when SINR is 10dB, CDF for NoFFR is at 0.69 and for FFR-3 it is at 0.6 and for the proposed scheme it is at 0.5, which is less compared to the others, if CDF is lesser then data rate is higher and the femto users get optimum coverage.

Figure 5.8 depicts the outage probability of all the consumers with respect to the SINR threshold when 25 femtocells are redistributed in the macrocell. For a given SINR threshold, the proposed technique indicates a lesser outage probability than the techniques under comparison. It may also be noted that the proposed technique decrease the outage probability even at lower SINR threshold. Signal to interference noise ratio (SINR) with respect to outage probability shows that link performance is better.If we consider the point when the SINR at 10dB, for NoFFR the outage probability is 0.69, for FFR-3 it drops to 0.6 and for proposed scheme it further decreases to 0.5, which is less than the other two schemes. Similarly for the other SINRs a similar phenomenon is observed.

In the lower SINR regions of 5dB, in NoFFR the outage probability is 0.51 and in FFR-3 its value is 0.42 and in our proposed scheme it reduces to a mediocre 0.3. That means in lower SINR also the proposed scheme provides better performance than the other compared techniques. It not only suppresses the interference better than the others and increases the throughput and data rate but also it improves the coverage, even at lower SINR. It may be recalled that performance, data rate and throughput are inversely proportional to the Outage probability. Hence, if outage probability is less performance is enhanced. The simulation results prove the agility of the proposed scheme.
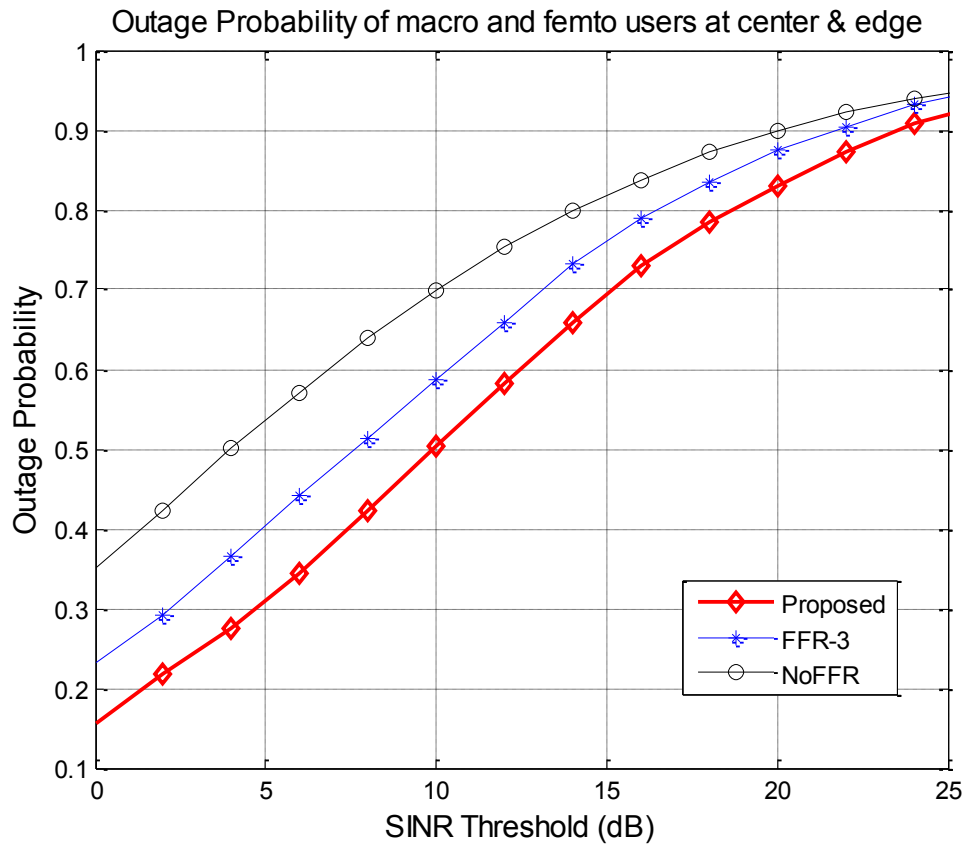
Figure. 5.8. Outage probability of macro and femto consumers, according to SINR threshold increases.

The proposed technique efficiently supports greater consumers, even when the interference is severe. These results have shown that, the proposed technique increase the overall throughput and decreases the outage probability, especially for the consumers even when they are in the edge region.

Chapter 6

CONCLUSION AND SCOPE FOR
FUTURE WORK

6. CONCLUSION AND SCOPE FOR FUTURE WORK

The demand of higher data rate and superior coverage can be fulfilled using femtocells. However, interference is a serious issue that can limit the performance of the LTE system. In this thesis LTE femtocells have been studied and the analysis has been broadly focused on interference in the macrocell and femtocell. Further analysis indicates that FFR is highly effective in interference mitigation. The research here addresses recourses management and interference mitigation issues. The simulation results prove the efficacy of the proposed scheme. The use of FFR maximizes the throughput, optimizes the SINR and CDF of femto cell users (FUEs) and provides increased overall system performance, and reduces the outage probability, especially for the cell edge users. This optimum combination should be able to reduce interference efficiently for the outdoor macrocell users and to provide better service to indoor users. The gains of the proposed scheme are 27% and 47% in average, compared to FFR-3scheme and NoFFR, respectively

In this thesis, we focused on analyzing the effects of femtocell deployment in the current cellular networks by predicting the interference experienced by an M-UE situated at a certain distance from the M-BS. The work presented in this thesis can be extended and enhanced in some specific areas. The future work could be the shrinking of cell size in the network to manage the interferences and Improvement of femtocells spectral efficiency. It would also be interesting to study the effects of femtocell deployment on the F-UEs such that we can predict the level of interference experienced by the F - UEs from neighboring femtocells with certain probability.

DISSEMINATION OF WORK:

Conferences Proceedings:

1. Chiranjibi Samal and Susmita Das, "By Fractional Frequency Reuse Mitigate Interference in Heterogeneous Femto and Macro Cell Networks", *Proceeding of IEEE International Conference on Green Computing, Communication and Electrical Engineering* (ICGCCEE'14), Coimbatore, India, March 06th - 08th, 2014.

2. Chiranjibi Samal and Susmita Das, "Interference Mitigation in Femtocell and Macrocell Networks Using Fractional Frequency Reuse", *IEEE sponsored 3rd International Conference on Computing of Power, Energy & Communication ICCPEIC -2014* , Melmaruvathur, kanchipuram, India, April 16th and 17th - 2014.

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